Water Saving Technologies as a Demand Management Option: Potentials, Problems and Prospects

A. Narayanamoorthy
Professor and Director, Centre for Rural Development, Alagappa University, Karaikudi – 630 003, Tamil Nadu, India

Introduction

Studies from different countries including India have corroborated that irrigation plays a paramount role in increasing the use of yield increasing inputs and enhancing cropping intensity as well as productivity of crops (Dhawan 1988; Vaidyanathan et al. 1994). Irrigation development also helps to increase employment opportunities and the wage rate of the agricultural landless laborers, both of which are essential to reduce poverty among the landless labor households (Narayanamoorthy 2001a; Bhattarai and Narayanamoorthy 2003; Narayanamoorthy and Deshpande 2003; Saleth 1997; Saleth et al. 2003). Nevertheless, water is becoming increasingly scarce worldwide due to various reasons (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, the problems of water scarcity are expected to aggravate further (see, Biswas 1993 and 2001; Rosegrant 1997; Rosegrant et al. 2002). Macro-estimates carried out by the International Water Management Institute (IWMI) indicate that one-third of the world population would face absolute water scarcity by the year 2025 (Seckler et al. 1998 and 1999). The worst affected areas would be the semi-arid regions of Asia, the Middle-East and sub-Saharan Africa, all of which are already having heavy concentrations of population living below the poverty line.

Though India has the largest irrigated area in the world, many regions are already reeling under severe water scarcity problems, partly because of the inefficient use of water. Owing to various reasons, the demand for water for different purposes has been continuously increasing in India, but the potential water available for future use has been declining at a faster rate (Saleth 1996; CWC 2004). The agricultural sector (irrigation), which currently consumes over 80 % of the available water in India, continues to be the major water-consuming sector due to the intensification of agriculture (see, Saleth 1996; MOWR 1999; Iyer 2003). In spite of having the largest irrigated area in the world, the coverage of irrigation is only about 38 % of the gross cropped area as of today in India. One of the main reasons for the low coverage of irrigation is poor water use efficiency under the flood (conventional) method of irrigation, which is predominantly practiced in Indian agriculture. Available estimates indicate that water use efficiency under the flood method of irrigation is only about 35 to 40 % (Rosegrant 1997).

Considering the availability of water for future use and the increasing demand for it from different sectors, a number of demand and supply management strategies have been introduced in India to augment the supply as well as to control the demand for water. One of the demand management strategies that was introduced recently to control water consumption in Indian agriculture is the drip method of irrigation (DMI). Unlike the flood method of irrigation, drip method supplies water directly to the root zone of the crop through a network of pipes with the help of emitters. Since it supplies water directly to the crop and not to the land as followed in the flood method of irrigation, the water losses occurring through evaporation and distribution are completely absent (INCID 1994; Narayanamoorthy 1996; 1997; 2001; Dhawan 2002). The on-farm irrigation efficiency of a drip irrigation system that is properly designed and managed is estimated to be about 90 %, while the same is only about 35 to 40 % for the surface method of irrigation (INCID 1994).

Objectives, Scope and Data

Among the various reasons for the slow progress made in the adoption of this new technology, its capital-intensive nature seems to be one of the main deterrent factors. Drip irrigation technology requires fixed investment that varies from Rs. 20,000 to Rs. 55,000 per hectare depending upon the nature of crops (wide or narrow spaced) and the material to be used for the system. Since the Indian farmers have been getting water at a low cost from the public irrigation system and also from well-irrigation (because of the introduction of flat-rate electricity tariff), there is less incentive for them to adopt this capital-intensive technology unless it is absolutely necessary. Moreover, since it involves fixed investment, farmers often ask questions like what will the water saving and productivity gains be? Is investment on drip irrigation economically viable? What will be the pay back period of the drip investment? These issues are raised because of the lack of sufficient credible field- based studies on DMI covering different regions of the country. Some of the studies have shown that the results derived from research station data are substantially different from that of survey data (see, Narayanamoorthy 2001).

In the absence of reliable field studies, it is difficult to judge the actual economic viability of drip method of irrigation (DMI). Keeping in view the various issues of drip method of irrigation, an attempt is made in this paper to review the adoption and impacts of water saving technology namely, drip method of irrigation in India using secondary data and available case studies. Specifically, the study discusses (a) the scope and rationale for the adoption of water saving technologies; (b) the government policies and programs being pursued to promote this technology; (c) the nature and extent of their actual adoption in different regions and cropping systems; (d) its impacts in terms of water saving and crop productivity; (e) economic viability of drip investment; and (f) the major issues and questions that require attention for future research and policy.

Data for this study has been used mainly from secondary sources published by government and other agencies, particularly, reports of the Indian National Committee on Irrigation and Drainage (INCID), the Central Board of Irrigation and Power (CBIP), the National Committee on Use of Plastics in Agriculture (NCPA) and the report of the Task Force on Micro-Irrigation (TFMI). In order to explain the farm-level issues and the position of drip method of irrigation, the author’s own studies on three different crops namely, sugarcane, banana and grapes, which were carried out in Maharashtra (an advanced state in terms of using drip irrigation) and Tamil Nadu, have been utilized (Narayanamoorthy 1996; 1997; 2001; 2005).

Water Saving Technologies: Rationale and Scope

The primary objective of introducing DMI is to reduce water consumption and increase water use efficiency in agriculture. However, it also delivers many other economic and social benefits to the society. Reduction in water consumption due to the drip method of irrigation over the surface method of irrigation varies from 30 to 70 % for different crops (INCID 1994; Narayanamoorthy 1997; Postal et al. 2001). According to data available from research stations, productivity gain due to drip method of irrigation is estimated to be in the range of 20 to 90 % for different crops (see INCID 1994). While increasing the productivity of crops significantly, the system also reduces the cost of cultivation substantially, especially in labor-intensive operations. The reduction in water consumption in drip method of irrigation also reduces the energy use (electricity) that is required to lift the water from irrigation-wells (see Narayanamoorthy 1996; 2001).

A few studies have been carried out focusing on the impact of the drip method of irrigation on various parameters in different crops over the last 10 years or so. Studies, by and large, have focused mainly on the impact of the drip method of irrigation on water saving, including water use efficiency, productivity of crops and cost of cultivation. While some have studied the impact of DMI on electricity saving, others have studied its economic viability in different crops, using both experimental and field survey data. Results of experimental data reported in INCID (1994) show that water saving in DMI over the method of FMI varies from 12 to 84 % in different vegetable crops. In the case of fruit crops, the lowest water saving was found to be 45 % (pomegranate), whereas the highest water saving is estimated to be 81 % (lemon). Water saving was also found to be 65 % in sugarcane and about 60 % in coconut. As in the case of INCID results, various studies reported in CBIP (1998 and 2001) also indicate a similar level of water saving in different crops. Similar to experimental data, studies carried out using field level data in Maharashtra also show that the water saving due to DMI is about 29 % in banana, 37 % in grapes and about 44 % in sugarcane (Narayanamoorthy 1996; 1997 and 2001).

Though DMI increases the crop productivity and saves a substantial amount of water, it requires relatively larger fixed investment to install the system in the field. Therefore, some studies have attempted to find out whether the investment in drip irrigation is economically viable or not in regard to different crops. While some have estimated benefit-cost ratio including water saving as well as excluding water saving (INCID 1994), others have estimated benefit-cost ratio and net present worth both with and without a subsidy condition (Narayanamoorthy 1997; 2001; 2004). The benefit-cost ratios provided for different crops in INCID (1994) indicate that investment in drip irrigation is economically viable, even after excluding water saving from the calculation. The estimated benefit-cost (B-C) ratio comes to 13.35 in crops like grapes and 1.41 in the case of coconut. However, it is not clear whether the B-C ratios presented in INCID (1994) are estimated using discounted cash flow technique or not. Unlike INCID estimates, using discounted cash flow technique and that too, utilizing field survey data covering three crops namely, grapes, banana and sugarcane, Narayanamoorthy (1997; 2001;

2004) estimated B-C ratio and net present worth. The results of these studies suggest that the investment in drip method of irrigation is economically viable even without a subsidy.

In spite of having many economic advantages over the method of flood irrigation, the coverage of area under drip method of irrigation is not appreciable in India except for a few states as of today. The area under DMI has increased from a mere 1,500 ha in 1985 to 70,859 ha in 1991-92 and further to 500,000 ha as of March 2003 (INCID, 1994; GOI, 2004). India has enormous potential for DMI. INCID (1994) report, which presents an overview about the development of drip irrigation in India, indicates that about 80 crops, both narrow and widely spaced crops, can be grown under DMI. Although DMI is considered to be highly suitable for wide-spaced and high-value commercial crops, it is also being used for cultivating oilseeds, pulses, cotton and even for wheat crops (INCID 1994). Importantly, research suggests that DMI is not only suitable for those areas that are presently under cultivation but it can also be operated efficiently in undulating terrain, rolling topography, hilly areas, barren land and even in areas which have shallow soils (Sivanappan 1994).

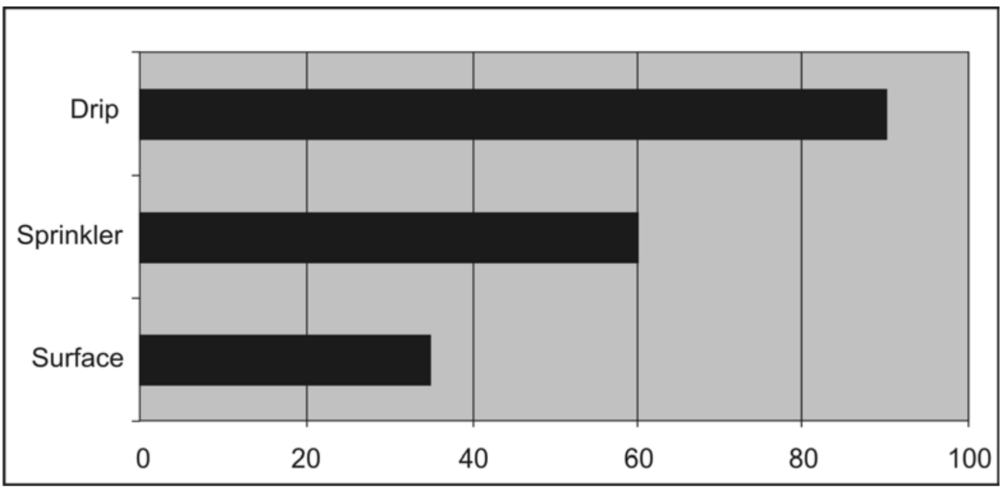
Role of Water Saving Technologies in Demand Management

Given the fast decline of irrigation water potential and increasing demand for water from different sectors, there is a need to conserve and increase the efficiency of water use so as to avoid a water crisis in the future. Drip irrigation technology is proved to be an important water-saving technology and, therefore, there are many justifiable reasons for adopting drip method of irrigation in countries like India. Some of these reasons are related to water availability and capital cost of irrigation, while others are related to production and productivity of crops, etc. The first and foremost reason for adopting DMI is the fast decline of irrigation water potential and growing demand for irrigation water. Up to 2001-02, about Rs. 1,360.65 billion (in current prices) have been spent exclusively for the development of irrigation by the government sector alone. As a result of this, area under irrigation has increased from 26.61 mha in 1950-51 to 86.67 mha in 1996-97, an increase of 2.60 % per annum. Despite the substantial increase of area under irrigation, the share of irrigated area to gross cropped area is only about 40 % as of today.

One of the main reasons for the limited expansion of area under irrigation is the predominant use of flood method of irrigation (FMI) for cultivating crops, where water use efficiency is very low due to various reasons. Water use efficiency under flood method of irrigation is estimated to be only around 40 % mainly due to huge losses through evaporation, conveyance and distribution (Sivanappan 1994; Rosegrant 1997; Rosegrant and Meinzen-Dick 1996). Unlike FMI, water use efficiency can be achieved over 90 % in DMI (see, Figure 1). Since water is supplied directly to the root zone of the crops using pipe network under DMI, the evaporation and distribution losses are completely absent under this method. Though FMI has been followed predominantly all over the world for cultivating crops, it is no longer desirable for countries like India, mainly due to the limited availability of water resources and growing demand for water for irrigation and other purposes. Therefore, for achieving sustainable agricultural development, it is essential to increase the existing water use efficiency for which drip method of irrigation can be one of the viable options.

India has the largest irrigated area in the world, but its water potential available for the future use of irrigation has been declining at a rapid pace since independence owing to various reasons (Saleth 1996; CWC 2004). As per the estimate of the Central Water Commission (CWC 1996; 2004), India's total irrigation potential is 139.9 mha. Of this total, about 58 mha (41.46 %) can be utilized from major and medium irrigation (MMI) sources and about 81.40 mha (58.54 %) can be utilized from minor irrigation (MI) sources. Up to 1999-2000, we have created about 94.73 mha of irrigated area, which accounts for about 67 % of the total potential (see, Table 1). Researchers have been cautioning that any additional creation of irrigation facility by constructing new major irrigation projects would not only require a huge cost but would also create adverse environmental problems (Singh 1997). However, considering the growth of population and the requirements of foodgrains in the future,[1] there is a need to increase the area under irrigation. One of the options available before us is increasing the existing water use efficiency in all sources of irrigation. Though many programs have been introduced to improve the existing water use efficiency under FMI, they have not been successful in bringing about the desired results up to now.[2]

Figure 1. Irrigation efficiency (in percentage) by irrigation methods.



[1] The Report of National Commission for Integrated Water Resources Development (1999) points out that India will require 320 million tonnes of foodgrains to feed a population of 1,333 million people in the year 2025 and 494 million tonnes of foodgrains to feed a population of1, 581 million people in the year 2050.

[2] Command Area Development (CAD) Program was introduced during the fifth 5-year plan with the aim of reducing the gap between the irrigation potential created and utilized. However, this program could not make any significant breakthrough in achieving its objectives and the gap between irrigation potential created and utilized has been increasing. The amount of money spent on CAD program was about Rs. 11,530.30 crore up to the 10th plan.

Table 1. Irrigation potential and utilization in India: Up to 1999-2000.

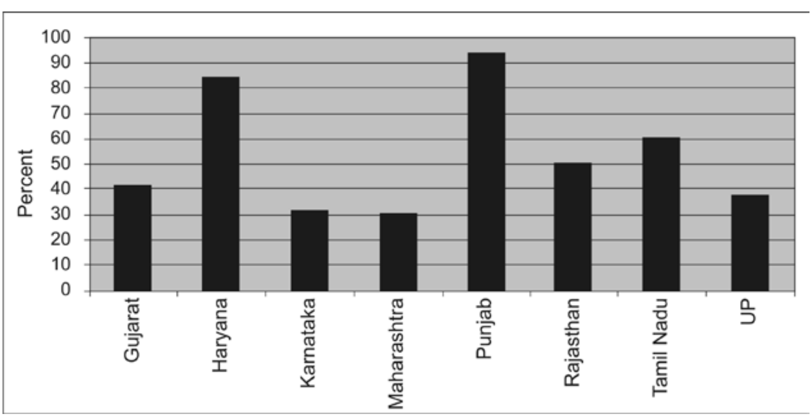
Particulars (1)	Potential (2)	Created (3)	Utilized (4)	(3)/(2) x 100 (5)	(4)/(3) x 100 (6)
MMI	58.50 (41.82)	35.35	30.47	60.43	86.20
MI:					
(a) Surface	17.40 (12.44)	12.26	10.86	70.46	88.59
(b) Groundwater	64.00 (45.75)	45.59	41.93	71.23	91.97
(c) Total	81.40 (58.18)	59.38	54.23	72.95	91.33
Total (MMI+MI)	139.90 (100.0)	94.73	84.70	67.71	89.42

Sources: CWC (1998 and 2002)
Notes: Bracketed figures are percentage to total; MMI – Major and Medium Irrigation; MI – Minor Irrigation

The irrigation potential available for future use has also been declining in many states. In fact, the condition is precarious in agriculturally advanced states like Punjab, Haryana and Tamil Nadu. The irrigation potential created to the total potential of MMI up to the ninth plan ranges from 69 to 103 % in states like Haryana, Punjab and Tamil Nadu. Similarly, the irrigation potential created to the total potential of MI also varies from about 53 to 123 % in states like Haryana, Punjab, Rajasthan, Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh (see, Narayanamoorthy 2002). Further exploitation of water through MMI and MI sources from these states certainly would create adverse environmental problems. Therefore, cultivating crops with the flood (conventional) method of irrigation is no longer desirable.

The state of groundwater is also precarious. The available groundwater for the use of irrigation has also been steadily declining in most of the agriculturally advanced states. The New Agricultural Technology (NAT) introduced during the mid-1960s has significantly increased the demand for irrigation water, which ultimately resulted in overexploitation of groundwater in many parts of India. Again the principal reason for the overexploitation of groundwater is the predominant cultivation of water-intensive crops under the flood method of irrigation. A recent state-wise estimate on groundwater potential and utilization has shown that the use of groundwater is going beyond the socially acceptable limit in many agriculturally advanced states (see, Figure 2). As a result of this, there is tremendous pressure on water resources now more than ever before, but the quantum of available water is fast declining.

Figure 2. Groundwater development in India: Selected states.



Another important reason for adopting WST in India is to reduce the ever increasing capital cost of surface irrigation development. A massive investment has been made exclusively for the irrigation development in India by the public sector over the years. As a result of this massive investment on irrigation, the total area under irrigation has increased from 22.61 mha in the pre-plan period (1950-51) to 86.26 mha in 2001-02. Though the massive investment on irrigation was justified by many experts in view of the nature of the Indian economy, capital cost required to create one hectare of irrigation has increased substantially, especially after the fifth 5-year plan. For instance, the requirement of investment (in current prices) for creating one hectare of irrigation in the MMI sector was only Rs. 1,513 in first 5-year plan, but the same increased to over Rs. 2,37,729 in 2001-02 (Gulati et al. 1994; Narayanamoorthy and Kalamkar 2004). One of the main reasons attributed for this huge increase in the requirement of investment per hectare is that the new irrigation projects are more capital intensive, as most of the easily available potential has already been exploited (Vaidyanathan 1999; Gulati et al. 1994).[3] Besides involving higher financial investment, the major irrigation projects are also capable of creating many social and environmental problems (Singh 1997; Rosegrant 1997).[4] Though drip method of irrigation is a capital-intensive technology, its capital requirement per hectare is relatively less when compared to the same required for MMI projects. In addition to this, the operation and maintenance costs of MMI projects have also been increasing due to various reasons (Gulati et al. 1994). Though drip irrigation cannot be a substitute for MMI projects, the cost-related problems associated with the large irrigation projects could be reduced to some extent by adopting drip method of irrigation at a large scale.

Third important reason for adopting WST is to increase production and productivity of agricultural commodities. Although the new agricultural technology has helped to increase production of food grains impressively from about 72 million tonnes in 1965-66 to over 211 million tonnes in 2001-02, the achievement in production of non-food grain commodities such as oilseeds, vegetables, fruits, etc, is not very impressive (Kumar and Mathur 1996).[5] Despite various efforts made by the policymakers, production (supply) of non-food grains is much less when compared to the domestic demand (Kumar and Mathur 1996). This has forced the government to import these commodities from other countries to meet the domestic requirements. Since most of the non-food grain crops mentioned above are cultivated predominantly under rain-fed conditions, where moisture stress is common, production of these commodities could not be increased to a desired level. Unlike FMI, the crops cultivated under DMI do not face any moisture stress as water is supplied on a continuous basis at the required level. The yield increasing inputs (e.g., fertilizers) applied for crops cultivated under the flood method of irrigation also do not fully reach the crops, due to leaching and other reasons. As fertilizers (liquid) can be supplied through water (which is called fertigation), the loss of fertilizers by way of leaching and evaporation is very less, hence high-level input

[3] The cost of irrigation per hectare in real term has also substantially increased over the years. The reasons for increasing real capital cost of new irrigation projects in different countries are discussed in Rosegrant (1997).

[4] It is reported by studies that though the benefits from Sardar Sarovar Dam (SSD) are large, the environmental and human costs of construction of dam are also estimated to be large. Some estimates indicate that SSD would flood about 37,000 hectares of forest and farmland (Rosegrant 1997).

[5] Even in cereal production the position is not very comfortable. Recent estimates relating to future demand and supply of cereals show that India will have cereal deficits of 36 to 64 million tonnes per year by 2020. A detailed account on India's cereal supply and demand is available in Bhalla et al. (1999).

use efficiency is possible under DMI. Since both moisture level and input use efficiency are maintained at a higher level under the drip method of irrigation, productivity of crops cultivated under the drip method of irrigation is significantly higher than those crops cultivated under FMI.

The production of foodgrains and other agricultural commodities have to be increased keeping in view the pace at which the population increases. The growth in foodgrains productivity was already very low during the 1990s (1.52 % per annum) when compared to the growth in the 1980s (2.74 % per annum)—(GOI 2002). Experience indicates that production of foodgrains also goes down sharply whenever fluctuations occur in rainfall. New areas with irrigation facility need to be brought under cultivation so as to avoid this problem. With the limited irrigation potential, creating irrigation facilities through MMI projects would cost more for the exchequer and also take a longer gestation period. Using the already exploited irrigation potential, the area under irrigation can be expanded further if drip method of irrigation is followed, as it requires less water when compared to flood method of irrigation.[6] Apart from water saving and productivity-related reasons, large-scale adoption of WST would also solve the ever increasing problems of electricity (energy) scarcity, waterlogging and other environmental problems, all of which one way or the other are associated with the present conventional method of irrigation.

Promoting Water Saving Technologies in India

Since drip method of irrigation is a new technology in India, introduced relatively recently, government-supported promotional programs have been in operation since the sixth plan. In fact, the promotional programs have made significant impact on the adoption of drip irrigation in India over the years, especially in states like Maharashtra and Andhra Pradesh, both of which are operating specific state supported schemes for promoting drip method of irrigation. Drip method of irrigation was introduced in India during the early 1970s at the Agricultural Universities and other Research Institutions. The scientists at the Tamil Nadu Agricultural University (TNAU), Coimbatore, who are considered to be the pioneers in drip irrigation research in India, have conducted large-scale demonstrations in farmers' fields for various crops, which received encouraging responses from the farmers (INCID 1994). However, the adoption of drip method of irrigation was very slow till the mid-1980s, mainly because of the lack of promotional activities from the State and Central Governments.

The formation of the National Committee on the Use of Plastics in Agriculture (NCPA) by the Ministry of Petroleum, Chemicals and Fertilizers, Government of India, during 1981 under the Chairmanship of Dr. G. V. K. Rao is termed as the first milestone for the development of micro-irrigation in India (GOI 2004). With the establishment of 17 different Plasticulture Development Centers (PDCs) across different agro-climatic regions in the country, the NCPA has played a crucial role in the technological development of micro-irrigation in India.[7] Besides recommending policy measures to the government, the NCPA also played an important role in

[6] According to an estimate of the World Bank, with a 10 % increase in the existing water use efficiency, India could add 7-8 mha of irrigated area without utilizing additional water resources (World Bank 1998).

[7] NCPA was later renamed as the National Committee on Plasticulture Applications in Horticulture (NCPAH) due to the prominent role plasticulture plays in the productivity of horticultural crops.

promoting drip method of irrigation through conducting seminars focusing on micro-irrigation and its beneficial impact (GOI 2004).

Apart from the government efforts, some research institutes and private drip set manufactures have also been playing an important role in promoting drip method of irrigation in India. For instance, The Report of Task Force on Micro Irrigation mentions "Jain Irrigation Systems Ltd., Jalgaon has been playing a pioneering role since its inception in 1989 for promoting micro irrigation" (GOI 2004 — p. 124). The establishment of the Jain Irrigation Systems Limited in 1988-89 marked a watershed in the spread of this technology. Their approach was unique, committed, scientific and persistent. A 'systems approach' from concept to commissioning was adopted by them. Learning from the mistakes and the short- comings of the past, this new company undertook extensive surveys in the market, interacted with scores of customers who had installed drip irrigation systems in their fields, critically evaluated its ills and took systematic and determined steps to remove these ills. The concept, in fact, was pioneered in the country by the Jain Irrigation, Jalgaon. A decade ago, the company established a 600-acre agro-related research and development farm at Jalgaon, where experiments on various aspects related to agronomy, irrigation, water management, watershed and wasteland development are now conducted on a regular basis.

Since drip irrigation is a new technology and a capital-intensive venture, the government operates schemes for drip irrigation with a subsidy. In states like Maharashtra, both the Central and State Governments are operating schemes for promoting the drip method of irrigation. Central scheme was started during 1982-83 (during the Sixth Plan) by the Ministry of Water Resources (Minor Irrigation Division), Government of India. Through this scheme, the Government of India provided a subsidy of 50 % to the farmers with a matching contribution from the State Governments for installation of micro-irrigation devices. Of the total amount of subsidy, 75 % was allocated for small and marginal farmers and the balance of 25 % for other groups of farmers. The Government of Maharashtra has made pioneering efforts for the successful adoption of drip irrigation system. For example, to make drip irrigation cost-effective, it provided subsidies to small and marginal farmers to the extent of Rs. 2,282.35 lakhs during the period 1986-1993 (INCID 1994). As per the latest information available from the *Economic Survey of Maharashtra: 2002-03*, an amount of Rs. 432 crore (Rs. 332 for drip irrigation and Rs. 100 crore for sprinkler irrigation) have been distributed to the cultivators in the form of subsidy by the government to promote micro-irrigation up to March 2002 (GOI 2003). Central scheme for drip irrigation was also introduced in the Seventh Plan with the following modifications:

a) The non-conventional energy devices like solar pumps and windmills were excluded from this subsidy scheme, as the same were included in the other schemes operated by the Department of Non-Conventional Sources of Energy;

b) The subsidy was limited to the small and marginal farmers only, excluding other farmers from the scope of the scheme;

c) The percentage of subsidy eligible under the scheme was on par with the on-going Integrated Rural Development Program;

d) Farmers growing horticultural crops like grapes, papaya, areca nut and coconut were also eligible for the subsidy; and

e) SC and ST farmers belonging to small and marginal categories of the size of land- holding and co-operative community schemes of small and marginal farmers were provided with 50 % subsidy under the scheme.

However, the central scheme of drip irrigation did not get a good response during the Seventh Plan since the subsidy was limited to only small and marginal farmers. Furthermore, due to capital paucity this group could not afford the drip systems even at the subsided rate. After knowing the ground realities, many new measures were incorporated under the new schemes introduced during the eighth plan. Under the new schemes, the subsidy amount is limited to either 50 % of the cost or Rs. 15,000/ha, whichever is lower. The Government of India has contributed the entire 50 % of the subsidy up to the financial year 1994-95. Thereafter the state governments have contributed 10 % towards the subsidy for the years 1995-96 and 1996-97, which, in fact, added up to 50 % with the center's contribution of 40 %. However, a beneficiary can avail a subsidy for a maximum area of one hectare only.

The subsidy scheme has undergone lot of changes over the years. During the period 1999-2000, the Government of India provided assistance for installation of drip for horticultural crops at 90 % of the cost of the system or Rs. 25,000/ha, whichever is less for small and marginal, SC/ST and women farmers, and 70 % of the total cost or Rs. 25,000/ha, whichever is less for other category of farmers. Assistance was also provided for drip demonstration at Rs. 22,500 or 75 % of the system cost per hectare, whichever is less (GOI 2004). It is to be noted that the rate of the subsidy tends to vary with the schemes implemented by the state. While most of the horticulture crops are included under the subsidy scheme, water-intensive crops such as sugarcane are excluded from the subsidy scheme supported by the Central Government. However, states like Maharashtra have been providing a subsidy for the sugarcane crop, because of the increase in the consumption of water by sugarcane when cultivated under the surface method of irrigation.

Water Saving Technologies: Extent of Adoption[8]

Drip method of irrigation was initially introduced in the early 1970s by the agricultural universities and other research institutions in India, with the aim of increasing the water use efficiency in crop cultivation. The development of drip irrigation was very slow in the initial years and significant development has been achieved, especially since the 1990s. Due to various promotional schemes introduced by the Government of India and states like Maharashtra, area under the drip method of irrigation has increased from 1,500 ha in 1985 to 70,589 ha in 1991-92 and to 246,000 ha in 1997-98 (INCID 1994; AFC 1998). According to the latest information, the area under DMI is estimated to have been increased to about 450,000 hectares, which includes about 350,000 hectares covered under the Government of India Schemes (GOI 2004— p. 130). This estimate is based on the information available from GOI departments,

[8] Data availability on micro-irrigation (MI) is one of the serious constraints in India. In spite of the fact that most of the area currently cultivated under micro-irrigation is established through various government-sponsored schemes, coverage of area under MI by states, crops and farmers' category are seldom published by any single agency. This does not allow the researchers to study the trends and determinants of micro-irrigation across states in detail. It is pertinent to collect and publish the data on micro-irrigation periodically so as to strengthen the research on micro-irrigation.

which have been operating subsidy schemes for promoting the drip method of irrigation. However, as mentioned in the *Report of the Task Force on Micro-irrigation*, a large number of institutions, commercial organizations, universities, large public/private sector companies, NGOs, etc., in the country have taken up drip irrigation for their farms/crops, which does not get reflected in the data available with GOI departments. Therefore, approximately, another 100,000 hectares are covered under the drip system by these organizations, whereby the total area under the drip irrigation system in the country would be about 500,000 hectares as of March 2003 (GOI 2004— pp. 130-131).

Table 2. State-wise area under drip method of irrigation (DMI).

State	Area ('000 ha)			Percentage to Total Area		
	1991-92	1997-98	2000-01	1991-92	1997-98	2000-01
Maharashtra	32.92	122.995[a]	160.28	44.64	50.00	53.16
Karnataka	11.41	40.800[b]	66.30	16.17	16.58	18.03
Tamil Nadu	5.36	34.100	55.90	7.59	13.86	15.20
Andhra Pradesh	11.59	26.300	36.30	16.41	10.70	9.88
Gujarat	3.56	7.000	7.60	5.05	2.85	2.07
Kerala	3.04	4.865	5.50	4.30	1.98	1.50
Orissa	0.04	2.696	1.90	0.06	1.10	0.52
Haryana	0.012	1.900	2.02	0.17	0.77	0.55
Rajasthan	0.30	1.600	6.00	0.43	0.65	1.63
Uttar Pradesh	10.11	1.500	2.50	0.16	0.61	0.68
Punjab	0.02	1.100	1.80	0.03	0.45	0.49
Other States	2.127	1.150	5.40	3.00	0.47	1.47
Total	70.59	246.006	367.70	100.00	100.00	100.00

Sources:AFC (1998) and GOI (2004)
Notes: a- includes state subsidy scheme area of 58,498 ha.
b- includes area under central and state schemes for development of oil palm and sugarcane

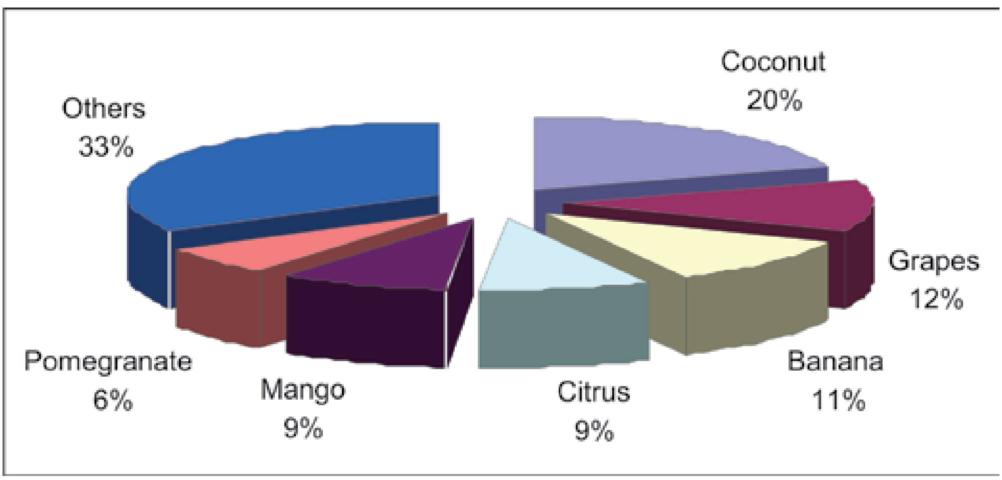
In spite of having many advantages over FMI, the development of drip irrigation does not match the expectations in most of the states. Table 2 presents state-wise area under drip method of irrigation for three time-periods namely, 1991-92, 1997-98 and 2000-01. It is evident from the table that the drip irrigated area has increased substantially between 1991-92 and 2000-01 in all the states of India. In all three time-periods, Maharashtra State alone accounted for nearly 50 % of India's total drip irrigated area followed by Karnataka, Tamil Nadu and Andhra Pradesh.[9] Over the last 10 years, significant growth has been achieved in

[9] There are many reasons for the rapid development of drip method of irrigation in Maharashtra. First, the state government is very keen in promoting drip irrigation on a large scale by providing a subsidy along with technical and extension services to the farmers. The Maharashtra Government has been providing a subsidy from 1986-87 onwards through state schemes. Second, the area under irrigation from both surface and groundwater is quite low and hence, many farmers have adopted the drip method of irrigation to avoid water scarcity, largely in divisions like Nashik, Pune, etc. Third, owing to continuous depletion of groundwater, farmers were not able to cultivate wide-spaced and more lucrative crops like grapes, banana, pomegranate, orange, mango etc., by using surface method of irrigation in many regions. As a result, farmers had to adopt drip irrigation as these crops are most suitable for it. Importantly, the farmers who adopted drip irrigation initially for certain crops have realized the importance of drip irrigation in increasing the water saving and productivity of crops. This has further encouraged many farmers to adopt the drip method of irrigation in some of the regions in Maharashtra.

the area under the drip method of irrigation in absolute terms in many states. However, drip irrigated area constitutes a very meager percentage in relation to the gross irrigated area and also in relation to its total potential area, which is estimated to be 27 mha by the Task Force on Micro-Irrigation (GOI 2004). For instance, during 2000-01, the share of drip-irrigated area to gross irrigated area was just 0.48 %, and about 1.09 % in relation to total groundwater irrigated area of the country.

Although over 80 crops are suitable for the drip method of irrigation, only a few crops have been dominant in the total area under drip irrigation so far. As of 1997-98, crops like coconut, grapes, banana, citrus, mango and pomegranate together have accounted for nearly 67 % of the total drip irrigated area (see Figure 3 and also Table 3). States like Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka account for a major share of the area in all these crops. More importantly, out of the total area of 26,460 ha of the banana crop, the Maharashtra State alone accounted for as much as 93 % at the end of 1997-98. It shows that the adoption of drip method of irrigation is very much concentrated only in a few states despite many different regions in the country experiencing severe water scarcities. It is essential to bring more water-intensive crops under the drip method of irrigation so as to avoid aggravating the supply-demand gap in irrigation water in the future.

Figure 3. Crop-wise share of drip irrigated area in India: 1997-98.



Who is using DMI in India? Do farmers use DMI without a subsidy being given by state agencies? Unfortunately clear answers are not available for these questions from the existing reports and studies, despite the fact that the drip method of irrigation has been promoted by the government over the last 15 years or so. However, a nationwide study carried out by the Agricultural Finance Corporation (AFC1998) reveals that the drip method of irrigation is still essentially considered to be the scheme of the government. As of 1997-98, the area under DMI other than government schemes (without subsidy) accounted for only about 18 % of India's total drip irrigated area, indicating that farmers are reluctant to adopt drip irrigation without subsidy. Studies need to be carried out as to why the individual farmers without subsidy are not willing to adopt DMI, despite the substantial benefits that can be derived from it.

Water Saving Technology: Economic and Resource Impacts

It has been proved by some studies that the drip method of irrigation helps to save water and improves water use efficiency, reduces the cost of cultivation and increases productivity of crops and farm income (INCID 1994). While reducing water consumption, it also reduces by a substantial amount, the electricity required for irrigation purposes, by reducing the number of working hours of irrigation pump-sets (Narayanamoorthy 1996a). Normally, the impact realized using experimental data may not match the field data because of varying agro-economic conditions between the two-settings. Therefore, we have discussed the impact of DMI on different parameters using both the experimental and field data.

Table 3. Drip method of irrigation: Water saving and productivity gains.

Crop's Name	Water Consumption (mm/ha)		Yield (tonne/ha)		Water Saving over FMI (%)	Yield Gain over FMI (%)	Water Use Efficiency$	
	FMI	DMI	FMI	DMI			FMI	DMI
VEGETABLES								
Ash gourd	840	740	10.84	12.03	12	12	77.49	61.51
Bottle gourd	840	740	38.01	55.79	12	47	22.09	13.26
Brinjal	900	420	28.00	32.00	53	14	32.14	13.13
Beetroot	857	177	4.57	4.89	79	7	187.53	36.20
Sweet potato	631	252	4.24	5.89	61	40	148.82	42.78
Potato	200	200	23.57	34.42	Nil	46	8.49	5.81
Lady's fingers	535	86	10.00	11.31	84	13	53.50	7.60
Onion	602	451	9.30	12.20	25	31	64.73	36.97
Radish	464	108	1.05	1.19	77	13	441.90	90.76
Tomato	498	107	6.18	8.87	79	43	80.58	12.06
Chillies	1,097	417	4.23	6.09	62	44	259.34	68.47
Ridge-gourd	420	172	17.13	20.00	59	17	24.52	8.60
Cabbage	660	267	19.58	20.00	60	2	33.71	13.35
Cauliflower	389	255	8.33	11.59	34	39	46.67	22.00
FRUIT CROPS:								
Papaya	2,285	734	13.00	23.00	68	77	175.77	31.91
Banana	1,760	970	57.50	87.50	45	52	30.61	11.09
Grapes	532	278	26.40	32.50	48	23	20.15	8.55
Lemon	42	8	1.88	2.52	81	35	22.34	3.17
Watermelon	800	800	29.47	88.23	Nil	179	27.15	9.07
Mosambi	1,660	640	100.00	150.00	61	50	16.60	4.27
Pomegranate	1,440	785	55.00	109.00	45	98	26.18	7.20
OTHER CROPS:								
Sugarcane	2,150	940	128.00	170.00	65	33	16.79	5.53
Cotton	856	302	2.60	3.26	60	25	329.23	92.64
Coconut	--	--	--	--	60	12	--	--
Groundnut	500	300	1.71	2.84	40	66	292.40	105.63

Sources: INCID (1994) and NCPA (1990)
Notes: $ - water consumption (mm) per quintal of yield

One of the prime advantages of drip irrigation is that it saves a substantial amount of water as compared to conventional methods of irrigation. Though studies using field level data are rarely available, focusing on water use efficiency and water saving of DMI, many research stations situated in different parts of the country have evaluated the water saving capacity of DMI for different crops. We have presented the water requirements, saving of water and water use efficiency under DMI and FMI for different crops in Table 3 based on the data from experimental stations. The water saving capacity of DMI is expected to be different for different crops as the consumption and the requirement of water varies from crop to crop. As expected, the water saving for vegetable crops varies from 12 to 84 % per hectare over the conventional method of irrigation. In fruit crops, water saving varies from 45 to 81 % per hectare over the conventional method of irrigation. In crops like cotton, coconut and groundnut, water saving varies from 40 to 60 % per hectare. Importantly, water saving in sugarcane, which is one of the water-intensive crops, is over 65 % per hectare when compared to the conventional method of irrigation.

Similar to the results available from INCID (1994) report, various experimental studies carried out by the Precision Farming Development Centre (PDCs) also clearly demonstrate that water saving due to DMI is substantial over the method of surface irrigation in different crops (see, GOI 2004). Water saving under the drip method of irrigation occurs mainly because of three reasons. First, since water is supplied through a network of pipes, the evaporation and distribution losses of water are minimal or completely absent under DMI. Second, unlike FMI, water is supplied under DMI at a required time and required level and thus, over-irrigation is totally avoided. Third, under the conventional method of irrigation, water is supplied for the whole of cropland, whereas DMI irrigates only the plants. Though the results of the experimental data discussed above clearly suggest that water saving due to DMI is substantial, one cannot completely rely on these results because the environmental conditions that are prevailing under experimental stations are totally different the conditions prevailing at the farmers' field. Therefore, we discuss below the water saving including its efficiency under DMI using farm level data in the context of three crops namely sugarcane, banana and grapes.

Water consumption per hectare for any crop is determined by factors like horse power of the pump-set, water level of the well, capacity of the pump, size of delivery pipes, condition of the water extraction machineries (WEMs), distance between place of water source and field to be irrigated, quality of soil, terrain condition etc. These factors vary considerably across farms. Pump-sets with higher horse power (HP) lift more water per unit of land compared to the pump-sets with lower horse power. Most of the studies based on research station data have measured water consumption in terms of centimeter (CM) in drip irrigation. But, in practice, measuring water in terms of CM is not an easy task at the field level as HP of the pump-sets and water level of the well changes considerably across the farms. In order to avoid these difficulties, water consumption is measured in terms of horse power (HP) hours of irrigation.[10]

[10] HP hours of water is computed by multiplying HP of the pump-set with hours of water used.

Table 4 presents per hectare consumption of water in terms of HP hours for drip and non-drip adopters for all three crops—sugarcane, grapes and banana. It is clear from the table that the consumption of water by crops under the drip method of irrigation is significantly less than that of the flood method irrigation (FMI). While water saving in sugarcane comes to about 44 %, the same is estimated to be about 37 % in the case of grapes and about 29 % in the case of banana. Among these three crops, water saving in terms of HP hours is much higher for the banana crop as compared to the other two crops. Drip method saves about 3,245 HP hours of water per hectare for banana, while it is about 1,412 HP hours for sugarcane and about 1,968 HP hours for grapes. The requirement of water varies for each crop depending upon the soil quality and other factors and, therefore, the saving of water due to DMI is varied among the three crops discussed. As mentioned earlier, unlike flood method of irrigation, since water is supplied only at the root zone of the crops and that too at a required quantity, water losses occurring in the form of evaporation and distribution are completely absent under DMI. This helps DMI adopters to save water considerably as compared to the non-adopters of DMI. Though there are differences in water saving between the three crops, the study shows that drip technology helps saving relatively more water in water-intensive crops like banana.

Table 4. Water use efficiency in drip and non-drip irrigated crops.

Particulars	Method	Sugarcane	Grapes	Banana
Water Consumption (HP hours/ha)	DMI	1,767.00	3,310.38	7,884.70
	FMI	3,179.98	5,278.38	11,130.34
Yield (quintal/ha)	DMI	1,383.60	243.25	679.54
	FMI	1,124.40	204.29	526.35
Water Use Efficiency (HP hours/quintal)	DMI	1.28	13.61	11.60
	FMI	2.83	25.84	21.41

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

While the consumption of water per unit of area is a good indicator to measure the efficiency of water use in drip and non-drip crops, water consumed to produce one unit of crop output is the most appropriate method to judge the efficiency of water consumption in DMI and FMI. In order to study the water use efficiency under the two methods of irrigation, we have calculated water consumption required producing one unit of output under drip and non-drip irrigated conditions. As reported by experimental data based studies, the results of field data also show that water use efficiency (WUE) is substantially higher for drip-irrigated crops as compared to the same cultivated under flood method of irrigation (see, Table 5). The analysis shows that sugarcane cultivated under drip method of irrigation consumes only 1.28 HP hours of water to produce one quintal of output when compared to 2.83 HP hours of water for producing the same quantity of output under non-drip irrigated condition, i.e., to produce one quintal of sugarcane under non-drip irrigated condition about 1.55 HP hours of additional water is consumed.

Table 5. Electricity consumption by drip and non-drip irrigated crops.

District	Electricity Consumption (Kwh/ha)		Electricity Saving over FMI		
	DMI	FMI	In percentage	In quantity (Kwh)	In money value (Rs)*
Sugarcane	1,325.25	2,384.99	44.43	1,059.74	3,454.75
Grapes	2,482.77	3,958.78	59.45	1,476.01	4,811.80
Banana	5,913.53	8,347.75	41.16	2,434.00	7,934.80

Source: Estimated using Narayanamoorthy (1996, 1997 and 2001)

Notes: * - Rs.3.26/Kwh, which is the current (2003-04) average cost of electricity supply in Maharashtra State, is assumed to estimate electricity saving in terms of money value

Similar to sugarcane crop, water required to produce one quintal of output in banana and grapes is also found to be substantially lower under DMI as compared to their counterpart. Under DMI, banana consumes only 11.60 HP hours of water to produce one quintal of banana output as against the use of 21.14 HP hours of water for the same quantity of yield under non-drip irrigated method. In the case of grapes, each quintal of output involves the use of just 13.60 HP hours of water under DMI as compared to the use of 25.84 HP hours under non-drip irrigated method. The fact that comes out clearly from the analysis is that DMI not only reduces the per hectare consumption of water but also reduces the water required to produce one unit of crop output substantially when compared to the flood method of irrigation.

Along with water, electricity (energy) used for lifting water from wells is also saved considerably due to the drip method of irrigation. Water saving and electricity saving are highly interrelated under DMI and, therefore, an analysis on electricity use under drip method is presented in this section. It is observed in the foregoing section that HP hours of water used per hectare of crop under DMI are significantly less than those of FMI. Therefore, it follows simply that the consumption of electricity also reduces significantly under DMI. We have estimated electricity consumption based on the hours of pump-set operations for both the drip adopter and the non-drip adopter groups. For estimating the quantum of electricity saved, it is assumed that for every hour of operation of a pump-set, 0.750 kwh of power is used per HP.[11]

Since all the farmers in both the groups have used only electrical pump-sets, we have simply multiplied HP hours of water with assumed power consumption of 0.75/kwh/HP to arrive at the per hectare electricity consumption. The estimated consumption of electricity (in kwh) presented in Table 5, clearly depicts that farmers using DMI utilized a lesser amount of electricity as compared to FMI farmers in all three crops. Farmers who cultivated sugarcane under DMI could save about 1,059 kwh of electricity per hectare as compared to those farmers who cultivated sugarcane under FMI. Similarly, while the farmers cultivating grapes could save about 1,476 kwh/ha of electricity due to DMI, the saving of electricity is estimated to be about 2,434 kwh/ha in banana in comparison to the farmers who cultivated the same crop under FMI with a similar environment. The substantial amount of electricity saving due to DMI is not a surprising result, because any reduction in consumption of water would ultimately lead to reduction in the consumption of electricity.

[11] Details of consumption of electricity by pump-sets and the relevant estimates can be seen from Shah (1993).

Farmers with drip irrigation operate pump-sets for a fewer number of hours and therefore, consumption of electricity is quite low. Since the saving of electricity through the drip method of irrigation is very high, it would help to reduce the total electricity bill to be paid by the farmers. We have estimated the money saved in the total electricity bill per hectare through energy saving. Since Maharashtra State Electricity Board supplies electricity on a flat-rate (FR) basis for agriculture, it was not possible to get per kwh price of electricity. Therefore, we have assumed Rs. 3.26/kwh, which is the current average cost of electricity supply in Maharashtra, as a nominal rate to estimate the saving of electricity in monetary terms. In accordance with this, on an average, about Rs.3,454/ha can be saved on the electricity bill alone by cultivating sugarcane under the drip method of irrigation. Similarly, farmers cultivating grapes and banana under DMI can save about Rs. 4,811and Rs. 7,934 per hectare, respectively. It suggests that the drip irrigation technology helps to reduce the cost of cultivation enormously by reducing the cost of electricity besides helping to save precious inputs like electricity and water.

As in water consumption, the energy used to produce one quintal of crop output is computed by dividing the per hectare energy (electricity) consumption by yield of each crop per hectare. Electricity consumed to produce one quintal of sugarcane is quite low for drip adopters in Maharashtra. For instance, on an average, sugarcane cultivators under DMI used about 0.968 kwh to produce one quintal of sugarcane, whereas the same is estimated to be about 2.121 kwh for those who cultivated sugarcane under FMI. This means that for every quintal of sugarcane production about 1.163 kwh of electricity can be saved through drip method of irrigation. Electrical energy consumed to produce one quintal of crop output is also found to be low for drip adopters in banana and grapes as well. While grapes cultivators under DMI used about 10.21 kwh to produce one quintal of grapes, the non-drip adopters have used about 19.37 kwh. A similar trend is observed in the case of banana crop as well. Obviously, higher productivity and relatively low amount of water consumption have reduced the per quintal requirement of electricity significantly in drip irrigated crops.

Drip method of irrigation also helps to reduce the cost of cultivation and improve productivity of crops as compared to the same crops cultivated under the flood method of irrigation. In this section, using both the experimental and field level data, we discuss the impact of DMI on the cost of cultivation and productivity of crops. First, we discuss the productivity enhancement in different crops due to DMI using experimental data and then we study the impact of DMI on the cost of cultivation and productivity of crops using field level data pertaining to three crops namely sugarcane, grapes and banana. It can be seen from the results of the experimental station data presented in Table 3 that the productivity of different crops is significantly higher under DMI when compared to FMI. Productivity increase due to drip method of irrigation is noticed over 40 % in vegetable crops such as bottle gourd, potato, onion, tomato and chilies, while over 70 % increase in many fruit crops. In the case of sugarcane, productivity difference is found to be over 33 %. Specific experiments carried out at *Punjabrao Krishi Vidyapeeth*, Akola, (Maharashtra State) on vegetable crops such as cauliflower, tomato and brinjal also suggest that productivity enhancement due to DMI is substantial (see, INCID 1994). Similar kinds of results have also been noted at different experimental stations located in different states.[12]

[12] More details on productivity on different crops cultivated using drip and flood method of irrigation can be seen from (INCID 1994; CBIP 1993; Verma and Rao 1998).

Though various studies using experimental data reported that DMI increases the productivity of crops, none of these studies seem to have compared the productivity of crops with the cost of cultivation. This is one of the major limitations of the existing studies, which are based on experimental data. There is a possibility that productivity of crops under DMI may be higher due to higher use of yield increasing inputs. Therefore, in order to find out the real impact of DMI on productivity of crops, one needs to compare the cost of cultivation of crops with the productivity of crops. Keeping this in view, an attempt is made below to relate the cost of cultivation with productivity of crops under DMI and FMI in the context of sugarcane, grapes and banana.

Studies carried out using experimental data in different crops underline that the DMI can reduce the cost of cultivation, especially in labor-intensive operations like weeding, irrigation, ploughing etc (see, INCID 1994; Dhawan 2002). When the labor cost reduces, the total cost of cultivation also reduces, because labor cost constitutes a considerable portion in the total cost of cultivation. Let us first study the cost of cultivation in the sugarcane crop. It is clear from Table 6 that drip irrigation reduces the total cost of cultivation by about Rs.6,550/ha (nearly 13 %) for the adopters as compared with the non-adopters with regards to the sugarcane crop. Though the total cost saving in terms of percentage is not very high in aggregate, it varies across different operations. Among the different operations, cost saving is very high in irrigation, furrows and bunding followed by seed and seed sowing. Saving under cost of cultivation is also found in fertilizers (about 8 %). This is because of the reason that some of the adopters have used liquid fertilizers and thus, the cost incurred on fertilizers is relatively less.

Table 6. Cultivation costs of adopters and non-adopters of drip method of irrigation (Rs/ha).

Operations	Sugarcane			Grapes			Banana		
	DMI	FMI	% change over FMI	DMI	FMI	% change over FMI	DMI	FMI	% change over FMI
Ploughing and Preparation	3,385	4,087	-17.18	5,918	6,131	-3.48	2,633	3,223	-18.30
Furrows and Bunding	1,433	1,837	-21.98	IUPP	IUPP	----	IUPP	IUPP	----
Seed and Seed Sowing	7,155	8,516	-15.98	DNC	DNC	----	5,331	5,416	-1.56
Fertilizers (in-organic)	9,396	10,253	-8.35	21,828	25,329	-13.83	16,378	17,494	-6.38
Farm Yard Manure	6,940	7,434	-6.65	13,273	16,410	-19.12	9,975	8,316	19.95
Pesticides	991	973	1.88	47,695	50,107	-4.81	10	---	---
Weeding and Interculture	4,583	5,208	-12.00	7,782	8,855	-12.11	1,826	2,123	-14.00
Irrigation[a]	5,676	7,195	-21.11	8,586	8,429		5,757	6,379	-9.75
Harvesting	b	b	----	14,256	11,908	19.72	4,613	5,547	-16.84
Transport and Marketing	b	b	----	3,966	5,322	-25.47	2,706	2,346	15.32
Others	2,434	3,037	-19.86	11,202	14,424	-22.34	2,207	1,895	-16.47
Total Cost	41,993	48,540	-13.49	134,506	147,915	-9.07	51,437	52,739	-2.47

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

Notes: a - Includes operation and maintenance costs of pump set and drip set; b - Costs of harvesting, transport and marketing are not included since sugar factories have incurred these costs; IUPP – Included under ploughing and preparation; DNC – Relevant data could not be collected as grape gardens are very old

A few earlier studies have reported that the drip method of irrigation also reduces the cost of fertilizers enormously as it can be supplied along with water – liquid fertilizers. Some of the farmers have argued that even without using the liquid form of fertilizers, the same can be reduced by avoiding wastage under the drip method of irrigation. Since water is supplied through a pipe network under the drip method of irrigation, it does not require more labor.[13] But, in the case of the surface method of irrigation, labor input is necessary to control water supply (changing course of water from one field to other) and to govern leakage and seepage. In addition to saving in the cost of labor, cost incurred on account of electricity (for operating pump-set) is also less as drip irrigation requires less amount of water when compared to flood method of irrigation. Under DMI, a saving of about 17 % in the cost of cultivation is noticed in ploughing and preparatory operations. This is because of the fact that the drip method of irrigation does not warrant much ploughing as it supplies water at the root zone of the crops. As indicated by earlier studies, the cost saving is also very high in weeding operation under DMI, which comes to about 12 % over the cost incurred by the farmers who cultivated sugarcane under FMI. Cost saving in weeding operation is high because it does not allow weed to come up in the non-crop space by not supplying water beyond the root zone of the crop. It should, however, be noted that the cost of cultivation varies with situational factors like soil quality, condition of the terrain, farmers' approach etc.

Farmers who cultivated grapes and banana under DMI have also incurred relatively lower cost of cultivation. In the case of banana, drip irrigation reduces the total cost of cultivation by about Rs. 1,300/ha as compared to the farmers who cultivated the same crop under the flood method of irrigation. Among the different operations, cost saving is very high in irrigation. Second highest saving under the cost of cultivation is noticed in the ploughing operation. This is because of the fact that drip method does not warrant much ploughing as it supplies water at the root zone of the crops. The cost saving is also high in weeding operation as indicated by earlier studies. Gain in cost of cultivation is relatively higher in grapes as compared to banana. In banana, cost saving due to DMI was only about 2.50 %, whereas the same is nearly 10 % in grapes. As in the case of banana crop, cost saving varies with operations in grapes as well. Cost saving is found to be higher in operations like weeding, irrigation, fertilizers and ploughing. On the whole, the major difference in cost of cultivation between the adopters and the non-adopters of DMI is observed in irrigation, weeding and inter-culture, ploughing and preparation, and seed and sowing.

Now let us turn our discussion to productivity gains using field data. One of the important advantages of the drip method of irrigation is productivity gain. Most of the time yield is affected because of moisture stress faced by crops. It is difficult to maintain water supply constantly for crops by the surface method of irrigation due to various reasons. Studies related to the drip method of irrigation have confirmed that the problem of moisture stress is completely reduced by providing irrigation through drip, as it supplies water at the root zone of the crops at a required frequency and quantity. As a result, the yield of crops cultivated under the drip method of irrigation is much higher than the crops which are cultivated under the surface method of irrigation.

Productivity of crops presented in Table 7 shows that it is significantly higher for the farmers who have adopted the drip method of irrigation as compared to the non-drip adopters

[13] INCID (1994) report mentions that one laborer can easily attend to up to 10 hectares under DMI, which is not possible under conventional method of irrigation.

in all the three crops selected for analysis. The yield difference in absolute terms between the adopters and the non-adopters of drip method of irrigation comes to nearly 259 quintals per hectare for sugarcane, a gain of 23 % over non-drip irrigated crop. In the case of grapes, the productivity difference between DMI and FMI adopters comes to about 19 % and the same comes to 29 % for the banana crop. The important point to be underlined here is that despite incurring more cost on yield increasing inputs, productivity of crops cultivated under FMI is significantly lower than that of DMI.

Table 7. Productivity of crops under drip and flood irrigated condition.

Crop	Productivity (quintal/ha)		Productivity increase over FMI	
	DMI	FMI	%	Quantity
Sugarcane	1,383.60	1,124.40	23.05	259.20
Grapes	243.25	204.29	19.07	38.96
Banana	679.54	526.35	29.10	153.19

Source: Computed from Narayanamoorthy (1996, 1997 and 2001)

There are three main reasons for higher yield in drip irrigated crops. First, the growth of crops cultivated under DMI is better because of lower moisture stress, which ultimately helps to increase the productivity. Second, unlike the surface method of irrigation, drip does not encourage any growth of weed, especially in the non-crop zone. But under the surface method of irrigation weeds consume a considerable amount of yield increasing inputs and thereby reduce the yield of crops. Third, unlike in the surface method of irrigation, fertilizer losses occurring through evaporation and leaching through water are less in the drip method of irrigation as it supplies water only for crop and not for the land. Though the expenditures incurred by the non-adopters on different yield-increasing inputs are more than those incurred by the adopters in all three crops, this ratio of expenditures does not coincide with the increased yield of crops. Therefore, one can conclude that this productivity enhancement in all three crops is the result of using the drip method of irrigation.

Besides increasing productivity of crops, DMI also increases cost efficiency, i.e., it reduces the cost required to produce a unit of crop output. This can be seen in Table 8. The estimated per quintal cost (calculated by dividing the total cost of cultivation with per hectare yield of three crops) shows that the non-adopters spend nearly Rs.13 more than the adopters to produce every quintal of sugarcane in Maharashtra. Likewise, in grapes, the non-adopters have incurred over Rs. 171 per quintal over the adopters, and in banana, the non-adopters have incurred nearly Rs. 30 to produce one quintal of output over their counterparts. It suggests that apart from increasing the productivity of crops, the drip method of irrigation also increases cost efficiency more substantially than the flood method of irrigation. On the whole, the analysis carried out using both the experimental and field level data clearly suggests that the drip method of irrigation increases productivity of crops, and that too with reduced cost of cultivation.

Table 8. Expenditure to produce unit of output under drip and non-drip condition.

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Yield (quintal/ha)	1,383.6	1,124.4	243.2	204.3	679.5	526.3
Cost of Cultivation (Rs/ha)	41,993.2	48,539.8	134,506.2	147,914.9	51,436.7	52,738.5
Cost of Production (Rs/quintal)	30.35	43.17	552.95	724.04	70.69	100.19

Source: Computed from Narayanamoorthy (1996, 1997 and 2001)

Economics of Water Saving Technology

It is clear from the above that drip method of irrigation reduces costs of cultivation, saves substantial amount of water and electricity and also enhances productivity of crops. Despite this, one of the important questions often asked about the drip method of irrigation is whether or not drip investment is economically viable to farmers cultivating crops using this new water saving technology. This question arises mainly because the drip method of irrigation requires a relatively large amount of fixed investment to install it in the field and, therefore, everyone (from policymakers to farmers) wants to know its economic viability in different crops. Though quite a few studies have analyzed the impact of drip method of irrigation on different parameters, not many studies have attempted to look into the economic viability of drip investment even by using experimental data. Some estimates on benefit-cost ratios are available from three secondary sources namely, INCID (1994); Sivanappan (1995) and AFC (1998). Although it is not clear whether the estimates available in these three studies were obtained using the discounted cash flow technique, let us discuss the results of these studies before going into analyzing the estimates made using field data.

The capital cost required for installing DMI for different crops has been increasing over the years due to the increase in the cost of materials used for manufacturing the drip system (GOI 2004). The capital cost of drip system largely depends upon the type of crop (whether narrow or wide-spaced crops), spacing followed for cultivating crops, proximity to the water source (distance between the field and source of water) and the materials used for the system. Wide-spaced crops, generally, require less capital when compared to the crops having narrow space, as the latter would require more laterals and drippers per hectare. INCID (1994) results, which are reported in Table 9, clearly indicate that the requirement of capital cost is much higher for banana (Rs. 33,765/ha) as compared to the same required for mango (Rs. 11,053/ha), which is a wide-spaced crop.

Table 9. Benefit-cost ratio of different drip irrigated crops.

Name of the Crop	Spacing (m x m)	Capital Cost (Rs/ha)	Benefit-Cost Ratio	
			Excluding Water Saving	Including Water Saving
Coconut	7.62 x 7.62	11,053	1.41	5.14
Grapes	3.04 x 3.04	19,019	13.35	32.32
Grapes	2.44 x 2.44	23,070	11.50	27.08
Banana	1.52 x 1.52	33,765	1.52	3.02
Orange	4.57 x 4.57	19,859	1.76	6.01
Pomegranate	3.04 x 3.04	19,109	1.31	4.40
Mango	7.62 x 7.62	11,053	1.35	8.02
Papaya	2.13 x 2.13	23,465	1.54	4.01
Sugarcane	Between biwall 1.86	31,492	1.31	2.78
Vegetables	Between biwall 1.86	31,492	1.35	3.09

Source: Compiled from INCID, (1994)

As regards B-C ratio, the results available from INCID (1994) show that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account the subsidy given to farmers. The B-C ratio estimated, excluding water saving, varies from 1.31 in sugarcane to as high as 13.35 in grapes. Obviously, the B-C ratio increases significantly further, when it is estimated after including the water saving. Various case studies reported in INCID (1994) also indicate that investment in drip irrigation is economically viable for different crops. Similar to INCID (1994), Sivanappan (1995) also estimated B-C ratio for different crops cultivated under DMI using data pertaining to the year 1993. It also suggests that the investment in drip irrigation is economically viable for different crops since the B-C ratio estimated was more than one. While the B-C ratio for pomegranate was estimated to be 5.16, the same is estimated to be 1.83 for cotton, which is a less-water intensive as well as a narrow-spaced crop.

Unlike the results reported in INCID (1994) and Sivanappan (1995), AFC (1998) estimated B-C ratio using field survey data collected from 3,850 sample farmers, consisting of beneficiary and non-beneficiary farmers. The survey covered 26 sample districts in 6 states. While the B-C ratio provided in AFC (1998) does not show the picture clearly, using the same data Dhawan (2002) has estimated B-C ratio for different crops at 12 % discount rate. Though the estimated B-C ratio appears to be very high, it is found to be relatively higher in all those districts belonging to the Maharashtra State as compared to the districts considered from other states. The inter-district variation in B-C ratio is possibly caused by inter-districts variation in the crop composition. The overall B-C ratio for the 21 sample districts or a drip investment of Rs. 27,000 is about 10, which is by any measurement extremely very high and attractive (Dhawan 2004).

Though B-C ratio available from different sources suggests that the investment in drip irrigation is economically viable for farmers, one cannot completely rely on these results because of the following reasons. First, the studies discussed above have not clearly mentioned as to how the income stream is estimated during the entire life period of a drip irrigation set. Second, studies, especially by Sivanappan (1995) and INCID (1994) have not mentioned the methodology that is followed for estimating the B-C ratio for different crops. These estimates also appear to be output-input ratio, but not Benefit-Cost ratio estimated using discounted cash flow technique. Third, the past studies on this aspect have been carried out either by a B-C analysis without proper methodology or relied on the experience of one or few farmers adopting DMI. Fourth, none of the above studies mentioned the assumptions that are followed for estimating B-C ratio. In view of the limitations of the available studies, there is a need to empirically evaluate the economic viability of DMI within a relatively more systematic methodological framework.

In order to evaluate the economic viability of drip investment in the context of three crops, we have computed both the net present worth (NPW) and the benefit-cost ratio (BCR) by utilizing the discounted cash flow technique. Since the NPW is the difference between the sum of the present value of benefits and that of costs for a given life period of the drip set, it collates the total benefits with the total costs covering items like capital and depreciation costs of the 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:

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

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

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).

Since drip irrigation involves fixed capital, it is necessary to take into account the income stream for the whole life span of drip investment. However, since it is difficult to generate the cash flows for the entire life span of drip investment in the absence of observed temporal information on benefits and costs, we need to make few realistic assumptions so as to estimate both the cash inflows and cash outflows for drip investment. These assumptions are:

1. The life period of the drip set is considered as 5 years for sugarcane and banana, but 10 years for grapes as followed by the INCID study (1994) as well as the experience gathered from the field.

2. The cost of cultivation and income generated using the drip method of irrigation is assumed to be constant during the entire life period of drip set in all three crops.

3. Differential rates of discount (interest rates) are considered to undertake the sensitivity of investment to the change in capital cost. These are assumed at 10 %, 12 % and 15 % as alternatives representing various opportunity costs of capital.

4. The crop cultivation technology is assumed to be constant for all three crops during the entire life period of drip set.

As a backdrop to our benefit-cost analysis of DMI, we first briefly discuss about the gross cost of production, profit without discount, capital cost (without and with subsidy) and the amount of subsidy received by the farmers. Table 10 presents the details of production, gross income and other details for the three crops namely, sugarcane, grapes and banana. To complete the analysis of the relative economics of DMI and FMI, we have calculated the relative profit levels of the three crops for the adopters and non-adopters of DMI. Profit of a crop is not only determined by its total quantity of output but also its quality. Prevailing market conditions also play a crucial role in determining the price of agricultural commodities. It has come out from the earlier studies that the drip method of irrigation not only helps in increasing the yield of the crops but also improves the quality of the product and fetches a higher price in the market (INCID 1994; Sivanappan 1994; Narayanamoorthy 1997).

Let us study how profit (undiscounted) varies between drip and non-drip irrigated crops in our study. While calculating profit, the total cost was calculated by considering only the variable costs but not the fixed cost components like interest rate and depreciation.[14] To calculate per hectare profit, we subtract the total cost of cultivation from the total income for the group of adopters and the non-adopters. The gross income (in rupees) is calculated by multiplying total yield with price received by the farmers for their crop output. It can be seen from Table 10 that per hectare profit[15] of the adopters in sugarcane is Rs. 27,424 higher than that of the non-adopters. In terms of percentage, profit of the drip adopters is higher by about 74 % over the profit of the non-drip farmers. This is not surprising, because on the one hand drip irrigation reduces the cost of cultivation of sugarcane and on the other hand it increases the yield of sugarcane.

[14] The cost of cultivation used in our analysis refers to cost A2, which includes all actual expenses in cash and kind incurred in production by owner plus rent paid for the leased-in land. See, CACP (1998) for more details about different cost concepts.

[15] This profit is calculated by deducting gross income from cost A2.

Table 10. Costs, income, and subsidy among drip and non-drip irrigated crops.

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Cost of cultivation (Rs/ha)[a]	41,993	485,39	134,506	147,914	51,436	52,738
Gross income (Rs/ha)	106,366	85,488	247,817	211,037	134,043	102,934
Profit (Rs/ha)[b] (Farm business income)	64,372	36,948	113,310	63,122	82,607	501,96
Capital cost of drip set (Rs/ha) (without subsidy)[c]	52,811	----	32,721	----	33,595	----
Capital cost of drip set (Rs/ha) (with subsidy)[c]	33,547	----	20,101	----	22,236	----
Subsidy (Rs/ha)	19,263	----	11,359	----	12,620	----

Source: Calculated from Narayanamoorthy (1996, 1997 and 2001)

Notes: a - production cost (A2) includes the operation and maintenance cost of drip set and pump-set; b - This is the difference between gross value of production and production cost (A2) and c - it does not include pump-set cost

In crops like grapes and bananas, the average profit among the drip adopters is significantly higher than that of the non-drip adopters. The profit level among drip adopters in grapes is Rs. 50,187/ha higher than that among non-adopters, whereas the same is about Rs. 32,400/ha for banana. While the profit differential is substantial for drip irrigated crops, it cannot be taken as a conclusive indicator of the comparative advantages of the new irrigation technique, as our profit calculation is based only on the variable cost but ignores fixed cost components like depreciation and interest accrued on the fixed capital while calculating the net profit. The life period of drip-set is one of the important variables which determines the per hectare profit. Moreover, since it is a capital-intensive technique, the huge initial investment needed for installing drip systems remains the main deterrent for the widespread adoption of DMI. To what extent this discouragement effect is real and to what extent such effect can be counterbalanced by a government subsidy are some of the important policy issues requiring empirical answers.

Fixed capital is needed for installing the drip method of irrigation. The magnitude of capital requirement varies with each crop depending upon certain factors as indicated earlier. Generally, wide-spaced crops require a relatively low-fixed investment and narrow-spaced crops need a higher-fixed investment. Besides the crop type, the proportion of the fixed capital requirement is also sensitive to the quality of the materials used for the systems as well as the distance between the water source (well) and the field (NABARD 1989). Let us now evaluate the empirical pattern of capital cost of the drip system, production cost (cost of cultivation) of crops and the amount of subsidy received by the sample farmers. Table 11 presents the details of capital cost and subsidy for all three crops. Since DMI is a capital-intensive technology, government provides nearly 50 % of the capital cost as subsidy to encourage the adoption of drip irrigation in crop cultivation. The average capital subsidy comes to Rs. 19,263/ha for sugarcane, Rs. 11,359/ ha for grapes and Rs. 12,620/ha for banana. As a proportion of the total capital cost of drip set, subsidy amount accounts for about 35 to 37 % among the three crops, which is within a limit of provision made by the government. With this background, let us analyze the benefit-cost pattern of drip investment using the discounted cash flow technique.

Table 11. Economic worth and benefits of drip irrigated crops with and without subsidy.

Particulars	Sugarcane		Grapes		Banana	
	without subsidy	with subsidy	without subsidy	with subsidy	without subsidy	with subsidy
Present Worth of Gross Income						
(Rs/ha)	356,645	356,645	1,243,794	1,243,794	449,449	449,449
At 15 % discount rate	412,902	412,902	1,400,166	1,400,166	483,228	483,228
At 12 % discount rate	434,206	434,206	1,522,588	1,522,588	508,026	508,026
At 10 % discount rate						
Present Worth of Gross Cost						
(Rs/ha)	186,749	169,990	692,574	703,553	201,696	191,814
At 15 % discount rate	198,546	181,343	777,909	789,179	215,431	205,287
At 12 % discount rate	207,254	189,725	844,677	856,148	225,484	215,159
At 10 % discount rate						
Net Present Worth (Rs/ha)						
At 15 % discount rate	169,896	186,656	551,220	540,241	247,753	257,635
At 12 % discount rate	214,357	231,558	622,257	610,987	267,797	277,941
At 10 % discount rate	226,952	244,481	677,911	666,440	282,542	292,867
Benefit Cost Ratio:						
At 15 % discount rate	1.909	2.098	1.795	1.767	2.288	2.343
At 12 % discount rate	2.079	2.277	1.799	1.774	2.243	2.353
At 10 % discount rate	2.095	2.289	1.802	1.778	2.253	2.361

Source: Computed from Narayanamoorthy (1996; 1997; 2001)

In order to assess the potential role that subsidy plays in the adoption of DMI, we have computed both the NPW and the BCR separately by including and excluding subsidy in the total fixed capital cost of drip set. Financial viability analysis under different rates of discount will indicate the stability of investment at various levels of the opportunity cost of investment. Although the BCR is sensitive to discount rate and the degree of such sensitivity depends on the pattern of cash flows, it is interesting to observe the sensitivity of the BCR when there is a simultaneous change in both subsidy and discount factors. Table 11 presents the results of a sensitivity analysis for sugarcane, grapes and banana crops computed under 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.

As regards the sugarcane crop, the NPW of the investment with subsidy is marginally higher than that of a 'no subsidy' option. At 15 % discount rate, the NPW of drip investment is about Rs. 169,896/ha without subsidy and Rs.186,655/ha with subsidy. This means that the subsidy enables the farmers to get an additional benefit of Rs. 16,759/ha. It can also be observed that the difference between the NPW under 'with subsidy' and 'no subsidy' scenarios is decreasing along with each increase in the discount rate. For instance, the NPW under without subsidy increased from Rs. 169,896/ha at a 15 % discount rate to Rs. 226,951/ha at a 10 % discount rate. Similarly, under subsidy, the NPW increased from Rs. 186,655/ha at a 15 % discount rate to Rs. 244,481/ha at a 10 % discount rate. Similar to this, under without subsidy condition, the BCR also increased marginally from 1.909 at a 15% discount rate to 2.095 at a 10 % discount rate. The higher BCR under subsidy suggests the positive effect of subsidy on the economic viability of the drip method of irrigation in sugarcane.

The NPW and BCR, which are estimated separately for banana and grape crops, reveal that the NPW of the investment with subsidy is marginally higher than that under `no subsidy' option for both these crops. For instance, at a 15 % discount rate, the NPW of drip investment for banana is about Rs. 247,753/ha without subsidy but Rs. 257,635/ha with subsidy. This means that the subsidy enables farmers to get an additional benefit of Rs. 9,882/ha. It can also be noted that the difference between the NPW under the two scenarios is decreasing along with each increase in the discount rate. The difference in NPW for the two scenarios which is Rs. 10,325 for banana and Rs. 11,471 for grapes at a 10 % discount rate declines to Rs. 9,882 and Rs. 10,979 for Banana and Grapes, respectively at a 15 % discount rate. This differential behavior of NPW across discount rates for the two crops is attributable to the observed differences in cash flows and cultivation practices and the assumed difference in drip set life span for the two crops. As can be seen from Table 11, the BCR without subsidy for banana is about 2.253 at a 10 % discount rate, and the BCR slides down to 2.228 at a 15 % discount rate. For grapes, in contrast, the BCR declines only marginally as the rate of discount increases. Although the same pattern of decline in BCR is observed across the discount rates even under the alternative scenario of cash flows with subsidy, the BCR is higher with subsidy than otherwise. This suggests the positive role that subsidy plays in improving the economic viability of DMI for our sample crops irrespective of the time preference of the farmers.

An important policy issue in the context of DMI adoption is the number of years needed to recover fully the capital costs involved in drip installation. The year-wise computation of NPW for sugarcane, banana and grapes clearly shows that farmers can recover the entire capital cost of the drip set from their net profit in the very first year itself. This finding contradicts with the general belief that the capital cost recovery for drip investment takes more time. More importantly, when farmers can recover the capital costs within a year, the role of the discount rate as a device to capture the time preference of farmers seems to be of considerably lesser importance than one might think. However, in order to have more definite answers to the economic and social viability of DMI, we need a social rather than the private cost-benefit evaluation that is being attempted here. A comprehensive evaluation can be done by incorporating both social benefits such as water saving, additional irrigation, lower soil degradation and retention of soil fertility, as well as the social costs in terms of the negative food and fodder in the crop pattern shift and labor displacement. On the whole, the BCR under different discount rates indicates that drip investment in three crops considered for detailed analysis remains economically viable even without subsidy.

Conclusions and Implications

The study clearly demonstrates that micro-irrigation has many advantages over the method of flood irrigation that is followed predominantly in India. The drip method of irrigation reduces cost of cultivation, weed problems, soil erosion and increases water use efficiency as well as electricity use efficiency, in addition to being a useful devise in reducing the over-exploitation of groundwater. However, despite providing substantial amount of subsidy, the spread and coverage of drip irrigation in India is not very encouraging today due to various reasons. There is a feeling among some quarters of policymakers and researchers that the adoption of the drip method of irrigation cannot be increased without providing a subsidy because of its capital-intensive nature. It is true that drip irrigation is a capital-intensive technology, but it does not mean that its adoption cannot be increased without a subsidy.

Subsidy can be a necessary condition for encouraging the adoption of drip method of irrigation but cannot be a sufficient condition for sustaining the growth of it, as many other factors determine the growth of drip irrigation adoption. Studies carried out using field level data covering three important crops clearly show that the investment in drip irrigation is economically viable even without the government subsidy. The estimated benefit-cost (BC) ratio varies from 1.73 to 2.23 among the three crops under 'no-subsidy' scenario. Even though subsidy is not needed to enhance the economic viability of the drip system, it is still needed to enhance the incentive for the widespread adoption of DMI, particularly among the resource-poor farmers (marginal and small categories). Subsidy can be phased out eventually once the new irrigation technology covered an adequate enough area to expand subsequently through the demonstration effect. The most important task standing before the policymakers is to find out ways and means to convince farmers about the economic and social feasibility of drip method of irrigation. Since it involves a relatively higher amount of investment, farmers often ask questions such as: What will be the payback period? Whether investment will be viable? How much will be the water saving? What will be the productivity gains? It appears that these questions arise mainly because of poor awareness about the social and economic advantages of drip technology. Therefore, efforts are needed to convince the farmers through the quality extension network. Many policy initiatives are needed to expand DMI in India, specifically, the following are critical.

First, by recognizing drip industry as an infrastructure industry as well as announcing a tax holiday for specific time periods to all those drip set industries, which produce genuine drip materials. Finally, the competition can be increased to bring down the cost of the system. The economic and environment viability of the low cost drip irrigation system being introduced by some companies should also be evaluated using farm-level data.

Second, the present subsidy scheme, which provides a uniform rate of subsidy for all crops, needs to be restructured taking into account the water consumption of the crops and level of groundwater exploitation of the region. A higher subsidy should be given for water-intensive crops, including sugarcane. Also areas with overexploitation of groundwater (dark areas) and water scarcity should be given a higher subsidy than water-abundant areas.

Third, for a speedy growth of drip irrigation, an interlinked special package scheme can be introduced. In such a scheme, priority must be given to providing bank loans for digging wells and electricity connection (pump-set) for those farmers who are ready to adopt the drip method of irrigation for cultivating any crop.

Fourth, sugar industries should play a proactive role in increasing the adoption of drip irrigation in sugarcane, using their close contract system with the cultivators. In spite of the fact that sugarcane consumes the bulk of the irrigation water in different states,[16] serious efforts are not taken to bring the sugarcane under the drip method of irrigation. Some target must be fixed for each sugar industry to bring the cultivation of sugarcane under the drip method of irrigation within a specific period.

[16] It is reported that in states like Maharashtra, sugarcane crop, which accounts for barely 2.50 % of the cropped area, consumes nearly two-third of the irrigation water. In spite of increasing the water rate for irrigation purposes periodically since 2000-01, the area under sugarcane in the state has been increasing continuously at a faster pace, which poses different challenges to the policymakers.

Fifth, inadequate information about the operation, maintenance as well as usefulness of drip irrigation is one of the main reasons for its uneven spread across regions in India. Even the adopters do not know fully how much of subsidy is available per hectare for different crops. Owing to poor exposure, farmers are reluctant to invest such relatively large amounts of money on drip irrigation. In fact, many farmers do not know the fact that drip irrigation can also be used efficiently and economically for crops like sugarcane, cotton, vegetables, etc. The extension network, which is currently operated mainly by government agencies, does not seem to be making any significant impact on the adoption of this technology. Therefore, there is a need to revamp the extension network to drip set manufacturers (public and private partnership) in order to improve the quality of the extension service.

Sixth, groundwater is the only source of water being used for drip method of irrigation in India. Since water use efficiency under surface sources (canal, etc.) is very low owing to heavy losses through conveyance and distribution, farmers should be encouraged to use water from surface sources for the drip method of irrigation. This can be done by allocating certain proportion of water from each irrigation projects exclusively for the use of micro-irrigation.

Seventh, one of the important reasons for the low spread of this technology even in the water-scarce area is the availability of highly subsidized canal water as well as electricity for irrigation pump-sets. Appropriate pricing policies on these two inputs may encourage the farmers to adopt this technology.

Eighth, though drip irrigation has been in use in different states since the mid-80s, no agency has a clear idea about the potential of micro-irrigation in each state. Therefore, it is essential to prepare a state-wise and crop-wise potential area for DMI. A detailed estimate on the state-wise potential would be useful to fix the target to be achieved and also formulate schemes for the promotion of the drip method of irrigation.

Finally, state-sponsored schemes are not formulated in most of the states except in Maharashtra and Andhra Pradesh. All other states have been operating schemes mainly with the support of the central government (known as centrally-sponsored schemes), which started in 1990-91. Considering the water scarcity, it is essential to have separate state-sponsored schemes in each state to promote micro-irrigation by following the experience of Maharashtra State.

With regards to future research, more and more research studies need to be carried out pertaining to its economics and adoption using field survey data to strengthen the policy decision and provide feed-back about the issues pertaining to the drip method of irrigation to policymakers. The research findings available at present on drip irrigation are not adequate enough to provide answers to questions such as: Who are the adopters of drip method of irrigation? What are the characteristics of the adopters? Can small and marginal farmers adopt drip irrigation without subsidy? What are the problems of the present subsidy scheme and how to revamp the same? Why do farmers not adopt drip irrigation for cultivating crops like pulses, oilseeds and other similar crops? What is the economic and environmental impact of DMI? Can DMI be used to solve the problem of overexploitation of groundwater? What is the economic viability of different crops cultivated presently under DMI? Unless adequate answers are made available to these questions, we may not be able to make judicious policy decisions to expand the adoption of this water saving technology at a fast rate.

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