MICRO-IRRIGATION AND ELECTRICITY CONSUMPTION LINKAGES IN INDIAN AGRICULTURE: A FIELD BASED STUDY

A. Narayanamoorthy*

ABSTRACT

Drip method of irrigation (DMI) introduced to improve the water-use efficiency has been practiced in different parts in India since early eighties. Quite a few studies have analysed the impact of drip method of irrigation on water use efficiency, water saving, cost of cultivation, labour use, productivity of crops, etc. using both experimental and farm level survey data in India. However, studies have not analysed the linkages between the adoption of DMI and electricity use in different crops using farm level survey data in Indian agriculture. DMI reduces the working hours of pumpsets through water saving and therefore, it reduces the consumption of electricity and also increases the efficiency of electricity use substantially. An attempt is made in this study to find out the linkages between the adoption of DMI and electricity use on three water-intensive crops namely banana, grapes and sugarcane, using farm level survey data collected from 200 farmers selected from Maharashtra, a western State of India. The study shows that farmers cultivating crops under DMI could save about 29 to 44 percent of electricity over the farmers who have cultivated the crops under flood method of irrigation. Electricity saving in terms of money value is estimated to be in the range of Rs. 3400-7900/ha in three crops selected for analysis.

1. Introduction:

There is a close nexus between groundwater irrigation development and electricity use in Indian agriculture. Macro level data clearly suggests that the electricity consumption in agriculture has been increasing along with the increase in groundwater irrigated area (TERI, 2006). For instance, while the area under groundwater irrigation increased from 8.65 mha in 1965-66 to 33.64 mha in 2002-03, the electricity consumption also increased from 1892 million kwh to 84486 million kwh during this period (see, Narayanamoorthy 1999; CMIE, 2005). Since most of the pumpsets used for lifting water from wells are being operated using electricity, the use of electricity in agriculture has obliviously increased over the years. Though the impact of electrically operated pumpsets in increasing the cropping intensity, productivity of crops, etc., has been clearly documented in India, it is argued in recent years that the electricity in agriculture is not used efficiently mainly because of cultivation of crops predominantly under conventional flood method of irrigation as well as subsidised electricity supply to agricultural consumers (see, Vaidyanathan 1996 and 1999; World Bank, 2001).

Widespread cultivation water-intensive crops under conventional method of irrigation started more significantly since the introduction of green revolution in India.[1] Available studies show that electricity is not used efficiently in agriculture due to pre-dominant use of conventional flood method of irrigation (FMI), where conveyance and distribution losses of water is substantial. Estimates indicate that water use efficiency

* Reader, Gokhale Institute of Politics and Economics, Pune – 411 004, Maharashtra State, India. Fax: +91-20-25652579; Tel: 25650287; 25654288 / 89; E-mail: na_narayana@hotmail.com

under flood method of irrigation is only about 35 to 40 percent (Sivanappan, 1994; Rosegrant, 1997; Rosegrant and Meinzen-Dick, 1996). Drip method of irrigation (DMI) introduced during the eighties, specifically to improve the water-use efficiency has been practiced in different parts in India. Unlike 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 (see, Figure 1.). Since it supplies water directly to the crop, instead of land, as followed in the flood method of irrigation, the water losses occurring through evaporation and distribution are completely absent (INCID, 1994, Narayanamoorthy, 1995; 1997; Dhawan, 2002). The on-farm irrigation efficiency of properly designed and managed drip irrigation system is estimated to be about 90 percent, which is substantially higher than the efficiency realised through flood method of irrigation (INCID, 1994).

Though drip irrigation technology is introduced primarily to increase the water use efficiency in agriculture, it also delivers many other economic and social benefits to the society. Reduction in water consumption due to drip method of irrigation over the surface method of irrigation varies from 30 to 70 percent 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 percent for different crops (see, INCID, 1994). While increasing the productivity of crops significantly, it also reduces the cost of cultivation substantially especially in labour-intensive operations.

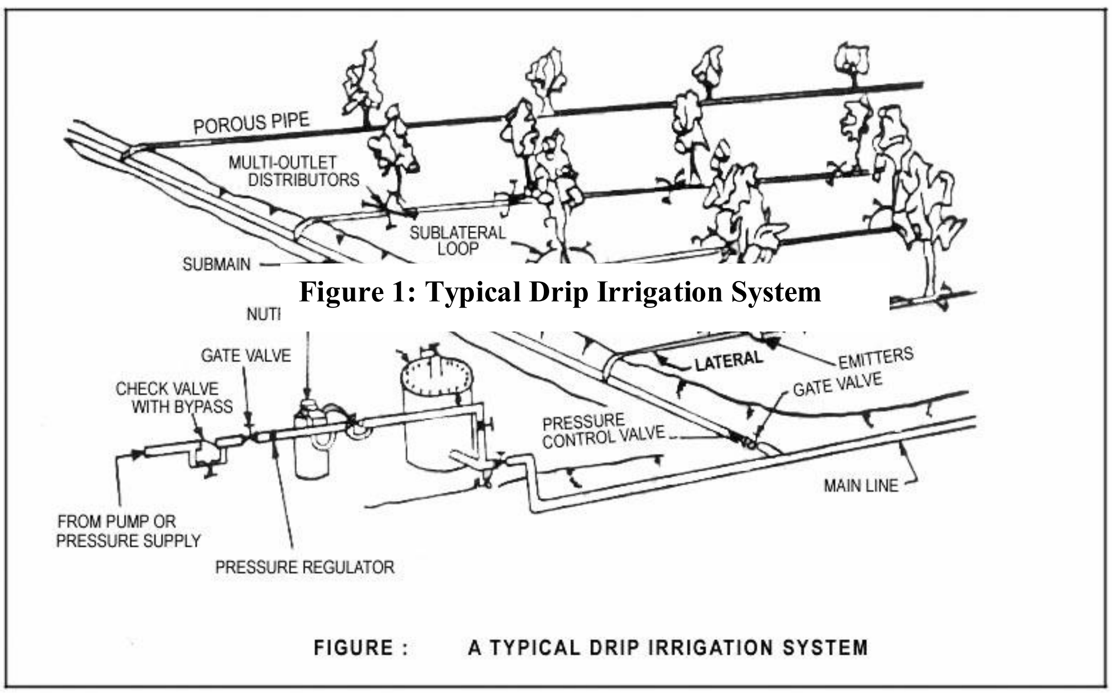


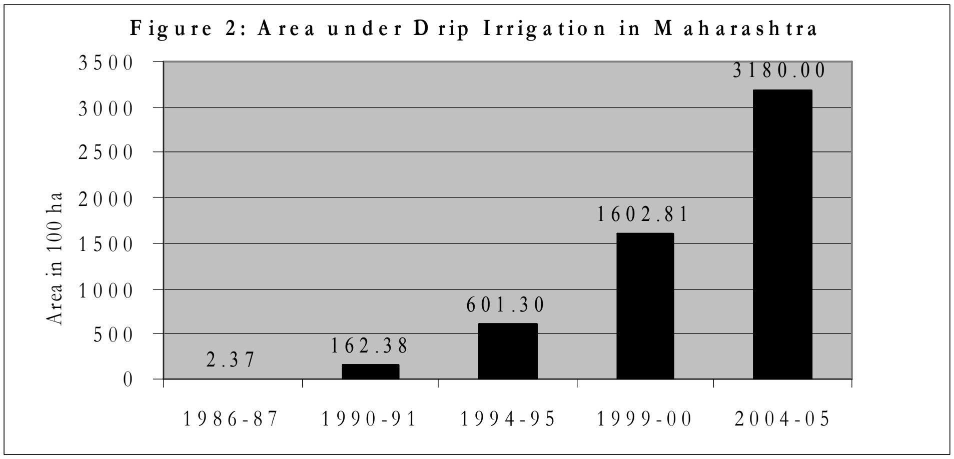
Figure 1: Typical Drip Irrigation System

Though DMI increases the crop productivity and saves 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 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 under with and without subsidy condition (Narayanamoorthy, 1996; 1997; 2001 and 2004). The benefit-cost ratios provided for different crops in INCID (1994) suggest that investment in drip irrigation is economically viable, even after excluding water saving from the calculation. The estimated benefit-cost ratio comes to 13.35 in crops like grapes and 1.41 in the case of coconut. Studies based on field survey data on different crops also suggest that the investment in drip method of irrigation is economically viable even without subsidy (see, Narayanamoorthy, 1997, 2001 and 2004).

It is clear that quite a few studies have analysed the impact of drip method of irrigation on water use efficiency, water saving, cost of cultivation, labour use, productivity of crops, etc., using both experimental and farm level survey data in India. However, studies have not analysed the linkages between the adoption of DMI and electricity use in different crops, especially using farm level survey data in Indian agriculture. Since DMI reduces the working hours of pumpsets through water saving, it not only reduces the consumption of electricity per hectare but also increases the efficiency of electricity use (electricity consumed per unit of output) to a great extent. In this study, therefore, an attempt is made to find out the linkages between the adoption of DMI and electricity use on three water-intensive crops namely banana, grapes and sugarcane, using farm level survey data collected from 200 farmers selected from Maharashtra, a western State of India. The specific objectives of the study are: (a) To analyse the impact of DMI on water use pattern and water use efficiency in three water intensive crops, (b) To estimate the electricity consumption of drip and non-drip irrigated crops so as to find out the electricity saving, (c) To estimate the electricity consumption per unit of crop output in both drip and non-drip irrigated crops, and (d) To estimate the electricity saving in terms of money value per hectare.

2. Study Area:

The study has been carried out in Maharashtra state, which is located in western part of India. Maharashtra is one of the water scarce states in India. Area under irrigation in the state is only about 17 percent of the gross cropped area, which is quite low compared to many states and to the national level average of about 42 percent as of today. Despite severe water scarcity, water intensive crops such as sugarcane, banana and other corps have been extensively cultivated using surface (flood) method of irrigation in the state. Studies have confirmed that sugarcane not only consumes bulk of the available water but the returns per unit of water is also very low (Rath and Mitra, 1989). Given the limited availability of irrigation water, over exploitation phenomenon and lower percentage of irrigated area, there is an urgent need to increase the efficiency in the existing use of irrigation water in the state. State government has been promoting drip irrigation by providing subsidy to the farmers since the mid-eighties. Due to concerted efforts taken by the government agencies along with some drip set manufacturers, the area under drip irrigation increased from 236 hectares in 1986-87 to 3.18 lakh hectares in 2004-05[2] (see, Figure 2). The state also has a distinction in accounting for the highest area under drip method of irrigation. For instance, at



the end of March 2003, India's total drip irrigated area created through various state sponsored schemes was five lakh hectares (GOI, 2004). Of this total, Maharashtra state alone accounted for over 63 per cent. Drip method of irrigation has also already made significant advantages especially in water use efficiency and productivity in crops like banana, grapes and sugarcane in the state (Narayanamoorthy, 1997a; 1997b; 2001; 2004b). The situation of water balance in the state requires an efficient use of water by optimising the returns per unit of water. Therefore, from the point of view of water scarcity and efficiency angle of water use, Maharashtra becomes the most obvious choice to empirically study the linkages between the adoption of drip method of irrigation and electricity use in agriculture.

3. Data and Method:

This study is completely based on the data collected from the sample farmers who have cultivated crops using drip and flood method of irrigation in three crops namely banana, grapes and sugarcane.[3] In order to study the impact of DMI on electricity use in sugarcane cultivation, the study area and the sample farmers have been selected using the following procedure. Since the adoption of drip irrigation technology is not uniform across the districts of Maharashtra, two important districts from the state where drip irrigation is being extensively used for cultivating sugarcane have been selected with the help of secondary data collected from Drip Irrigation Cell, Commissionerate of Agriculture, Government of Maharashtra, Pune. District-wise data on drip-irrigated area pertaining to the year 1998-99 was used for selecting two important districts. The two selected districts as per this method are Pune and Ahmednagar. In 1998-99, Pune (23.30 percent) and Ahmednagar (19.43 percent) together have accounted for 42.73 percent (398.29 ha) of total area under drip irrigated sugarcane in Maharashtra. Similar to the method followed for selecting the districts, two important blocks, one from each district, where area under drip irrigated sugarcane is higher, have been selected using the information supplied by the respective Agricultural Officer of the respective district. The two blocks selected in this method are Baramati from Pune district and Shrirampur from Ahmednagar district. As regards selection of farmers, from each district, 50 farmers consisting of 25 adopters and 25 non-adopters have been selected. Thus, a total of 100 sample farmers, 50 drip adopters and 50 non-drip adopters have been selected from the two selected districts to conduct detailed field survey on sugarcane crop. The field level information from the sample farmers has been collected pertaining to the year 1998-99.

In the case of grapes and banana crops, the sample for the study is designed as follows. First, based on the secondary data collected from the drip irrigation cell, Commissionerate of Agriculture, Government of Maharashtra, Pune, two districts with a relatively more extensive use of DMI were selected. The two districts selected are: Nashik and Jalgaon. Notably, these districts are dominant in terms of the area under DMI (about 27 per cent of the state total DMI area in 1994-95) since the introduction of the state scheme in 1986-87. Second, since the economic impact of drip irrigation varies by crop, two dominant crops in terms of the area under DMI - one from each sample district – have been selected. Based on the crop and block-wise distribution of the area under DMI as obtained from the Agricultural Officers of the respective districts, two crops, i.e., banana for Jalgaon district and grapes for Nashik district have been selected. Third, having identified the crops, two blocks - Niphad from Nashik district and Raver from Jalgaon district - with an extensive cultivation of these sample crops have been selected for a detailed field survey. And, finally, with the help of the adopters' list available for 1992-93, 50 farmers consisting of 25 adopters and 25 non-adopters of DMI have been selected for each district. It is this sample of 100 farmers for whom the relevant data on the economics of DMI has been collected during the year 1993-94.

In Maharashtra, farmers who are having own well (groundwater) are only using drip method of irrigation. Therefore, only those farmers who cultivate these crops using groundwater source of irrigation under both drip and flood irrigated condition are considered for this study. This is followed specifically to avoid the differential impact of source of irrigation on productivity of crops. While the drip adopters were selected on the basis of random sampling method, the farmers who cultivated the selected crops using flood method of irrigation (groundwater as source) nearest to the field of drip adopters have been selected purposively as non-drip adopters. This is followed specifically to reduce the differences in soil quality and other agro-economic factors between the two categories of farmers. The impact of drip method of irrigation on parameters such as water use pattern, water consumption, productivity of crops, electricity saving, etc., have been studied by comparing the same with the flood method of irrigation.

4. Relative Economics of Drip and Non-Drip Irrigated Crops:

Though the main objective of the paper is to study the linkages between the drip method of irrigation and electricity use in three different crops, let us briefly discuss about the relative economics of DMI before studying the linkages between the two. **Table 1** presents evidence for the differential pattern of productivity and cultivation cost among the adopters and non-adopters of DMI for three crops selected for the analysis. The cost of cultivation is comparatively lower among the adopters of DMI for all the three crops. DMI reduces cost of cultivation by about Rs. 6547/ha (13.49 percent) for sugarcane over the same crop cultivated under FMI. In the case of banana, DMI reduces cultivation cost by about Rs. 1,300/ha (2.47 per cent) whereas the reduction is about Rs. 13,400/ha (9.07 per cent) for grapes. Among the different constituents of operational cost, significant reduction occurs in components like the labour cost of irrigation, weeding, fertilisers and ploughing. Since DMI supplies water through a network of pipes, it obviously requires lesser labour time as compared to FMI. Similarly, since water is supplied only at the root zone of the crops under DMI, there is no scope for weed growth in non-crop area.

Table 1: Relative Economics of Drip and Non-Drip Irrigated Crops

Parameters	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Number of sample farmers	50	50	25	25	25	25
Land size (ha)	2.90	2.72	2.04	2.25	2.11	2.49
Land use intensity (%)	93.80	94.10	99.70	100.00	97.40	100.00
Cropping intensity (%)	208.50	205.50	219.25	242.10	245.70	208.90
Irrigation intensity (%)	220.40	220.50	224.70	236.70	266.00	241.65
Cost of cultivation (Rs/ha)[a]	41993	48540	134506	147915	51437	52739
Productivity (quintal/ha)	138.40	112.40	243.25	204.30	679.50	526.35
Gross income (Rs/ha)	106366	85488	247817	211038	134044	102935
Profit (farm business income)	64373	36948	113311	63123	82607	50197
Capital cost drip set (Rs/ha)[b]	52811	--	32721	--	33595	--
Net present worth (Rs/ha)[c]	169896	--	540241	--	247753	--
B-C Ratio[c]	1.909	--	1.767	--	2.228	--

Note: a – refers to cost A2; b – capital cost without subsidy; c – computed with 15 percent discount rate; cost of drip set does not include pumpset cost.

Sources: Narayanamoorthy (1996; 1997 and 2001).

Studies based on experimental data show that DMI also increases productivity of crops, which is also found to be true in our study. While the productivity of banana is only about 526 quintals/ha under FMI, the same is about 679 quintals/ha under DMI, indicating a gain of about 29 per cent. Likewise, the productivity difference is about 19 per cent for grapes and about 23 percent for sugarcane crop. This higher crop productivity under DMI occurs mainly through higher water use efficiency and intensity. Unlike FMI, since DMI supplies water continuously at regular intervals, the crops cultivated under DMI does not face moisture stress, the major factor negatively affecting crop yield (Sivanappan, 1994).

DMI reduces the cost of cultivation and increases the productivity of crops and therefore, the relative profit level of the adopters of DMI is also found to be higher than that of the non-drip adopters[4]. The average profit among drip adopters is significantly higher than that among non-drip adopters in the case of all the three crops. For grapes, the profit level among drip adopters is Rs. 50187/ha higher than that among non-adopters, whereas the same is about Rs. 32400/ha for banana and about Rs. 27425/ha for sugarcane. The benefit-cost ratio estimated using discounted cash flow technique at 15 percent discount rate shows that the drip investment in these three crops remains economically viable even without subsidy. With this background, let us now study the linkages between drip method of irrigation and water use as well as electricity consumption.

5. Pattern of Water Use:

Since there is a direct linkage between the use of water and electricity in different crops cultivated under drip and flood method of irrigation, let us first study the aspects of water use. Pattern of water use refers to number of irrigation used, hours required to irrigate one hectare of land, etc. Water use pattern of the farmers varies with the source of irrigation. In canal irrigated area, it is determined usually by the irrigation authorities. Similarly, in the tank irrigated area, pattern of water use is determined by the availability of water and the rainfall condition of the region. But farmers themselves determine the water use in groundwater area, as the farmers predominantly own the source. The control of state agency on water use is negligible in the groundwater-irrigated condition in India (see, Shah, et al, 2003). Since groundwater is essentially a private activity, the pattern of water use is significantly different than the surface source of irrigation. Studies have shown that efficiency of water use is significantly higher under groundwater irrigation when compared with canal and tank irrigation (Shah, 1993; Dhawan, 1988).

Table 2: Pattern of Water Use in Drip and Flood Irrigated Crops

Crop's Name	Method	HP of Pumpsets	Number of irrigation applied/ha	Hours used per irrigation/ha
Sugarcane	DMI	3.45	33.30	15.96
	FMI	3.65	25.34	35.16
Grapes	DMI	4.98	187.03	6.95
	FMI	8.94	104.37	18.89
Banana	DMI	9.82	139.14	5.33
	FMI	10.82	66.19	16.44

Source: Narayanamoorthy (1996, 1997 and 2001).

Since water is supplied through a pipe network in drip method of irrigation mainly using groundwater, the water supply can be controlled easily.[5] Therefore, pattern of water use under drip method irrigation is expected to be different from the same with the farmers who use flood method of irrigation. Therefore, we have tried to analyse the pattern of water use between the adopters of drip irrigation and the flood method of irrigation. For this, we have calculated number of irrigations used per hectare and hours of water used per irrigation by the two groups separately for all the three crops mentioned above. The results reported in **Table 2** show that the number of irrigation used per hectare is higher for the drip adopters among all the three crops. In sugarcane, the drip adopters have irrigated nearly eight times more than the non-drip adopters. Similarly, in banana, drip farmers have used nearly 73 irrigation more than the non-drip adopters. Likewise, in grapes, the farmers who have adopted drip method of irrigation (DMI) have applied nearly eight irrigation more than the non-drip adopters. Farmers with DMI use water at required frequency in order to maintain the moisture level and therefore, the actual number of irrigation used by the adopters is relatively higher than the non-drip adopters. Although farmers (adopters) are advised to supply water at least two times in a week for crops like sugarcane by the drip manufacturers for maintaining moisture level and better crop growth, most of the sample farmers did not follow this advise due to scarcity of water in the well and inadequate supply of electricity. Some of the farmers have argued that supply of water to sugarcane three to four times in a month under DMI is more than sufficient. Farmers belonging to the non-adopters group have irrigated about 25 times for sugarcane, which is approximately two times in a month.

Despite higher number of irrigation used by farmers with DMI in all three crops considered for the analysis, the time utilised in hours per irrigation is significantly less for the drip farmers. For instance, on an average, farmers cultivating sugarcane with DMI have used about 15 hours for each turn of irrigation, while the non-drip farmers used about 35 hours for each turn of irrigation. While farmers cultivating grapes with DMI have used almost 12 hours less for each turn of irrigation as compared to the non-drip counterpart, the banana cultivating farmers with DMI have used 11 hours less than the counterpart. Since drip method of irrigation supplies water only at the root zone of the crop, time required per irrigation is much less. But, farmers have to spend more time for each turn of irrigation under surface method, because it supplies water not only for the crop zone but also the non-cropped zone. Importantly, uneven land surface and water conveying channels also consume considerable quantity of water in surface method of irrigation. Evaporation losses are also very high in open water conveying channels that increases the requirement of time used in using water. But, these problems are meagre or completely absent under drip method of irrigation as it supplies water through pipe network. Interestingly, moisture stress faced by the crops reported to be higher under flood method of irrigation, in spite of higher amount of water supply for each turn of irrigation. Owing to changes in the pattern of water use between the two methods of irrigation, the quantity of water consumed by crops under the two methods of irrigation is expected to be varied substantially, which is analysed in the following section.

6. Water Consumption and Water Use Efficiency:

Water consumption per hectare for any crop is determined by factors like horse power of the pumpset, water level of the well, capacity of the pump, size of delivery pipes, condition of the water extraction machineries, distance between place of water source and field to be irrigated, quality of soil, terrain condition, etc. These factors vary considerably across farmers. Pumpsets with higher horse power lift more water from the wells as compared to the pumpset which has lower horse power. Most of the studies based on research station data have measured water consumption in terms of centimetre (CM) in drip irrigation. But, in practice, measuring water in terms of CM is not an easy task at field level as HP of the pumpsets and water level of the well changes considerably across the farmers. Because of these difficulties, we have measured water consumption in terms of horse power (HP) hours of irrigation. HP hours of water is computed by multiplying HP of the pump-set with hours of water used.

Consumption of water in terms of HP hours for drip and non-drip adopters for all three crops considered for analysis is presented in **Table 3**. It is clear that the consumption of water by crops under drip method of irrigation is significantly less than flood method irrigation (FMI). While water saving in sugarcane comes to about 44 percent, the same is estimated to be about 37 percent in the case of grapes and about 29 percent in the case of banana. Among three crops considered for the analysis, water saving in terms of HP hours is much higher for banana crop as compared to other two crops. For instance, drip method saves about 3245 HP hours of water per hectare for banana, while the same comes to only about 1412 HP hours for sugarcane and about 1968 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 here. 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 the DMI adopters to save water enormously as compared to the non-adopters of DMI. Though there are differences in water saving between the three crops, the study results clearly suggests that drip technology helps saving relatively more water in water-intensive crops like banana.

Table 3: Water Consumption by Drip and Non-Drip Irrigated Crops

Crop's Name	Water Consumption (HP hour/ha)		Water Saving over FMI	
	DMI	FMI	In Percent	In quantity
Sugarcane	1767.00	3179.98	44.43	1412.98
Grapes	3310.36	5278.38	37.28	1968.02
Banana	7884.70	11130.34	29.15	3245.64

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

Through the saving of water achieved due to the adoption of drip method of irrigation, it is also possible to increase the area under irrigation. In order to understand this, we have estimated how much of additional area can be brought under irrigation by saving water in all three crops. Our estimates show that with the saving of water (from one hectare), an additional area of about 0.80 ha can be brought under irrigation by adopting drip method of irrigation in sugarcane. Similarly, our estimate shows that an additional area of 0.60 ha (1.48 acres) under grapes and 0.41 ha (1.01 acres) under banana can be irrigated by adopting DMI. This reinforces the fact that DMI also significantly helps to bring additional area under irrigation through saving of water, besides providing various other benefits to the farmers.

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. This is also the simplest way to understand the importance of drip irrigation in increasing the efficiency of water use. As mentioned earlier, studies have proved that water use efficiency is higher in drip-irrigated crops, but most of them are based on research station data. We have calculated water consumption required producing one unit of output under drip and non-drip irrigated condition in order to study the water use efficiency under the two method of irrigation. Water consumption per hectare has been divided by the per hectare yield of crops to arrive at per quintal water requirement.

Table 4: Water Use Efficiency in Drip and Non-Drip Irrigated Crops

Particulars	Method	Sugarcane	Grapes	Banana
Water consumption (HP hours/ha)	DMI	1767.00	3310.38	7884.70
	FMI	3179.98	5278.38	11130.34
Yield (quintal/ha)	DMI	1383.60	243.25	679.54
	FMI	1124.40	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).

Water utilised to produce one quintal of crop output for all the three crops is given in **Table 4**. 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. Our estimate 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. 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 condition. 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 condition. What 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 flood method of irrigation. Besides water saving, drip method of irrigation also helps to save substantial amount of electricity used for lifting water from wells. Water saving and electricity consumption are highly interrelated under DMI and therefore, an analysis on electricity use under drip method is presented in the following section.

Table 5: Estimates of Electricity Consumption by Drip and Non-Drip Irrigated Crops

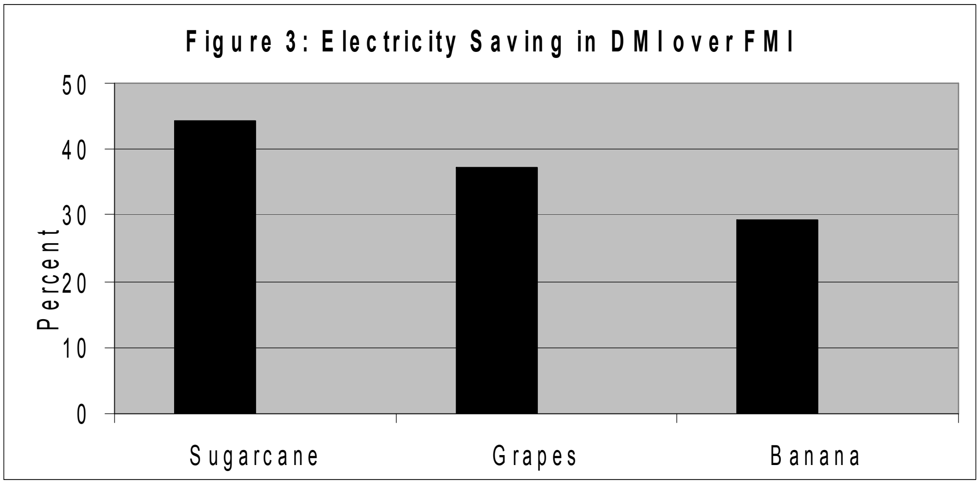
Crop	Electricity Consumption (Kwh/ha)		Electricity Saving over FMI		
	DMI	FMI	In Percent	In quantity (Kwh)	In money value (Rs)*
Sugarcane	1325.25	2384.99	44.43	1059.74	3454.75
Grapes	2482.77	3958.78	37.28	1476.01	4811.80
Banana	5913.53	8347.75	29.16	2434.00	7934.80

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.

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

7. Drip Irrigation and Electricity Use Linkages:

It is a known fact that due to rapid energisation of pump-sets and widespread cultivation water intensive crops, consumption of electricity by agricultural sector has increased manifold since independence.[6] In India, on an average, pumpset that is used to lift water from wells consumes about 70 percent of electricity in agriculture (Sharma, 1994). Though the increased consumption of electricity indicates better growth of agriculture, many researchers argue that electricity is not used efficiently in agriculture due to various reasons. One among the options available for increasing the efficiency of electricity use in agriculture is drip method of irrigation. Some preliminary level studies on drip method of irrigation have shown that the micro-irrigation technology is not only useful for reducing the consumption of water but also useful in energy saving (INCID, 1994). It is obvious that along with the number of working hours of pumpset the consumption of electricity also reduces in drip method of irrigation.



It is observed from the foregoing section that HP hours of water used per hectare of crop under DMI are significantly less than FMI. Therefore, it follows simply that the consumption of electricity also reduces significantly under DMI. In order to know the impact of drip method of irrigation on electricity saving, we have estimated electricity consumption based on the hours of pumpset operation for both the drip adopters and the non-drip adopters groups. As followed by the earlier studies, for estimating the quantum of electricity saved, we have assumed that for every hour of operation of pump-set, 0.750 kwh of power is used per HP (see, Shah, 1993). Since all the farmers in both the groups have used only electrical pumpsets, 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 utilised very less amount of electricity as compared to FMI farmers in all three crops. Farmers who cultivated sugarcane under DMI could save about 1059 kwh of electricity per hectare as compared to those farmers cultivated sugarcane under FMI. Similarly, while the farmers cultivating grapes could save electricity about 1476 khw/ha due to DMI, the saving of electricity is estimated to be about 2434 kwh/ha in banana over the farmers who cultivated the same crop under FMI with similar environment. The substantial amount of electricity saving due to DMI is not a surprising results, because any reduction in consumption of water would ultimately lead to reduction in consumption of electricity.

Table 6: Estimates of Electricity Use Efficiency in Drip and Non-Drip Irrigated Crops

District	Yield (quintal/ha)		Electricity Use (Kwh/ha)		Electricity Use Efficiency (Kwh/quintal)	
	DMI	FMI	DMI	FMI	DMI	FMI
Sugarcane	1383.60	1124.40	13252.50	23849.90	0.96	2.12
Grapes	243.25	204.29	2482.77	3958.78	10.21	19.37
Banana	679.54	526.35	5913.53	8347.75	8.70	15.86

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

Farmers with drip irrigation operate less number of hours of pumpsets and therefore, consumption of electricity is quite low. Since the saving of electricity through drip method of irrigation is very high, it would help to reduce the total electricity bill to be paid by the farmers. In order to find out this, we have calculated the money saved in the total electricity bill per hectare through energy saving. Since Maharashtra State

Electricity Board supplies electricity on 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. As per the estimate, on an average, about Rs.3454/ha can be saved on electricity bill alone by cultivating sugarcane under drip method of irrigation. Similarly, farmers cultivating grapes and banana under DMI can save about Rs. 4811/ha and Rs. 7934/ha respectively. This amply proves that the drip irrigation technology helps to reduce the cost of cultivation enormously by reducing the cost of electricity besides helping to save the precious inputs like electricity and water.

In order to explain efficiency of electricity consumption in drip method of irrigation, electricity consumed to produce one quintal of crop output is also worked out under both DMI and FMI conditions. As in water consumption, the energy used to produce one quintal of crop output is computed by dividing per hectare energy (electricity) consumption by yield of each crop per hectare. The estimate of electricity required to produce one unit of output under DMI and FMI conditions is presented in **Table 6**. As expected, 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. Similar trend is observed in the case of banana crop as well. Obviously, higher productivity and relatively low amount of water consumption have reduced per quintal requirement of electricity significantly in drip irrigated crops.

8. Conclusion:

Drip method of irrigation is introduced specifically to increase the water use efficiency in Indian agriculture during the eighties. Besides saving water, it also reduces the cost of cultivation, increases productivity as well as profit of crops. Quite a few studies have analysed the impact of drip method of irrigation on different parameters including its economic viability using both experimental and farm level survey data. Since DMI reduces the working hours of pumpsets through saving water, it not only reduces the consumption of electricity but also increases the efficiency of electricity use to a greater extent. However, not many studies have attempted to study the linkages between the two using farm level survey data in Indian agriculture. An attempt is made in this study to find out the linkages between the adoption of drip method of irrigation and electricity use in three water intensive crops namely sugarcane, banana and grapes, using data collected from 200 sample farmers from Maharashtra State, India.

The results of the study show that the pattern of water use for crops is totally different between the two methods of irrigation. The drip adopters have applied more number of irrigation per hectare when compared to the non-drip adopters in all the three crops considered for the analysis. But, hours required per irrigation to irrigate per hectare of sugarcane, grapes and banana are significantly less for the drip adopters as compared to the non-drip adopters. Water saving in sugarcane due to drip method of irrigation is about 44 percent, while the same is estimated to be about 37 percent in grapes and 29 percent in the case of banana. Sugarcane cultivated under drip method of irrigation consumes only 1.28 horse power (HP) hours of water to produce one quintal of sugarcane as against 2.83 HP hours of water under flood method of irrigation, i.e., about 1.55 HP hours of additional water is consumed to produce one quintal of sugarcane under flood method of irrigation. Banana crop under DMI consumes only 11.60 HP hours of water to produce one quintal of output as against the use of 21.14 HP hours of water under non-drip irrigated condition. Similar trend is observed in grapes as well.

Consumption of electricity per hectare is quite low for drip-irrigated crops as compared to the same crops cultivated with flood method of irrigation. Electricity saving due to DMI is estimated to be about 1059 kwh/ha for sugarcane, about 1476 kwh/ha for grapes and about 2434 kwh/ha for banana. Efficiency in electricity use is also found to be very high in all the three crops cultivated under drip method of irrigation. On an average, sugarcane cultivators under drip method of irrigation used about 0.958 kwh to produce one quintal of sugarcane as against the non-drip crop consumption of 2.121 kwh. While grapes cultivators under DMI have used about 10.21 kwh to produce one quintal of output, the non-drip adopters have used about 19.37 kwh. Similar trend is observed in banana crop as well. Electricity saving in terms of money value comes to about Rs.3454/ha for sugarcane, Rs. 4811/ha for grapes and Rs. 7934/ha for banana.

The findings of the study clearly suggest that there is a close nexus between the adoption of drip method of irrigation and electricity consumption in agriculture. Besides increasing efficiency of electricity use, the demand for electricity for agriculture purpose can be reduced considerably by adopting drip method of irrigation extensively. Currently, the supply of electricity throughout India falls short of the demand because of constraints in production. Supply of quality electricity is essential for the development of agriculture, but the "supply is neither reliable, available nor of the steady quality needed to avoid damaging the irrigation pumps it runs and severely disrupting irrigation and farming operations" (World Bank, 2001). Though drip method of irrigation provides lot of benefits including water and electricity saving, the coverage of drip area in relation to its potential area is very meagre as of today (see, Narayanamoorthy, 2004 and 2005)[7]. Subsidised electricity tariff and low canal water price prevailing in different parts in India are considered to be major impediments for the slow adoption of micro-irrigation technologies. While the targeted programmes on micro-irrigation would help to increase the coverage of area under water saving technology, restriction of cultivating water-intensive crops under conventional flood method of irrigation in those regions where groundwater has been falling down at a rapid pace would reduce the exploitation of groundwater. There is no doubt that the increased coverage of drip method of irrigation would solve the country's two major problems namely scarcity of irrigation water and poor availability of electricity, both of which are raising at a rapid pace in the recent years.

Notes:

1. The share of area under water intensive crops such as paddy, wheat, sugarcane, banana and other similar crops in the gross irrigated area has been increasing since the introduction of green revolution in Indian agriculture. Since these crops provide relative

higher profit, farmers tend to cultivate them predominantly under surface irrigation method using groundwater.

2. Government of Maharashtra has been providing substantial amount of subsidy for those farmers who are ready to adopt this new irrigation technology since mid-eighties. As of March 2005, the state government has distributed subsidy worth of Rs. 436.7 crore and brought about 3.18 lakh hectares of area under this method of irrigation. (see, GOM, 2006).

3. The field level data pertaining to three crops namely sugarcane, banana and grapes have been taken from the author's own study carried out in Maharashtra during different time periods. For details see, Narayanamoorthy, (1996, 1997 and 2001).

4. This profit is the difference between gross income (obtained by multiplying yield with the prevailing per quintal selling price) and cost of cultivation (cost A2). Since the total cost was calculated by considering only the variable costs and not the fixed cost components like interest rate and depreciation, it should be called as farm business income, instead of profit.

5. INCID (1994) report mentions that one labour can easily attend to drip method of irrigation up to 10 hectares. This is impossible under conventional method of irrigation.

6. Over the years, consumption of electricity in agricultural sector has increased significantly across regions in India, mainly because of rapid development of groundwater irrigation. Interestingly, the rate of increase in electricity consumption in agricultural sector was much higher than the total consumption. For more details regarding the trends and determinants of electricity consumption in Indian agriculture see, Narayanamoorthy (1999).

7. Due to various promotional schemes being operated by State and Central governments, the area under drip method irrigation has increased from 1500 ha in 1985 to over five lakh hectares in 2003. Though the development of drip irrigated area in absolute level is very significant, the coverage in relation to its total potential is very meagre as of today. The Task Force on Micro-Irrigation estimated that the total potential area available for drip and sprinkler method of irrigation is 27 mha and 69.5 mha respectively (see, GOI, 2004).

References:

Biswas, A. K. (2001), "Water Policies in Developing World", *Water Resources Development*, Vol. 17, No. 4, pp. 489-499.

CBIP. (1993), *Proceedings: Workshop on Sprinkler and Drip Irrigation Systems,* Central Board of Irrigation and Power, New Delhi.

CMIE. (2005), *Energy*, Centre for Monitoring Indian Economy, Mumbai, May.

CWC. (1996; 1998 and 2002), *Water and Related Statistics,* Ministry of Water Resources, Central Water Commission (CWC), Government of India, New Delhi.

Deshpande, R. S. and Narayanamoorthy, A. (2001), "Issues Before the Second Irrigation Commission of Maharashtra", Economic *and Political Weekly*, Vol. 36 No. 12, pp. 1034-1043.

Dhawan, B. D. (1988), *Irrigation in India's Agricultural Development: Productivity, Stability and Equity,* Sage Publications, New Delhi, India.

Dhawan, B. D. (2002), *Technological Change in Indian Irrigated Agriculture: A Study of Water Saving Methods*, Commonwealth Publishers, New Delhi.

GOI. (2004), *Report of the Task Force on Micro-Irrigation, Ministry of Agriculture*, Government of India, New Delhi.

GOM. (2006), *Economic Survey of Maharashtra: 2005-06*, Planning Department, Government of Maharashtra, Mumbai.

INCID. (1994), *Drip Irrigation in India*, Indian National Committee on Irrigation and Drainage, New Delhi.

Moench, Marcus (1994), *Groundwater Policy: Issues and Alternatives in South Asia*, National Heritage Institute, San Francisco, U.S.A.

Moench, Marcus and Dinesh Kumar (1997), "Distinction Between Efficiency and Sustainability", in Anil Agarwal (ed.), *The Challenge of the Balance: Environmental Economics in India*, Centre for Science and Environment, New Delhi, pp.305-309.

MOWR (1999), *Report of the Working Group on Water Availability for Use*, National Commission for Integrated Water Resources Development Plan, Ministry of Water Resources, Government of India, New Delhi.

Narayanamoorthy, A. & R. S. Deshpande (1997), *Economics of Drip Irrigation: A Comparative Study of Maharashtra and Tamil Nadu*, Mimeograph Series No. 47, Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune, India.

Narayanamoorthy, A. (1996), *Evaluation of Drip Irrigation System in Maharashtra*, Mimeograph Series No. 42, Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune, Maharashtra.

Narayanamoorthy, A. (1997), "Economic Viability of Drip Irrigation: An Empirical Analysis from Maharashtra", *Indian Journal of Agricultural Economics,* Vol.52, No.4, October-December, pp.728-739.

Narayanamoorthy, A. (1997b), "Beneficial Impact of Drip Irrigation: A Study Based on Western India", *Water Resource Journal,* No.ST/ESCAP/SER.C/195, December, pp. 17-25.

Narayanamoorthy, A. (1999a), "Changing Scenario of Electricity Consumption in Indian Agriculture", *Productivity*, Vol. 40, No.1, April-June, pp. 128-138.

Narayanamoorthy, A. (2001), *Impact of Drip Irrigation on Sugarcane Cultivation in Maharashtra*, Agro-Economic Research Centre, Gokhale Institute of Politics and Economics, Pune, June.

Narayanamoorthy, A. (2003), "Averting Water Crisis by Drip Method of Irrigation: A Study of Two Water-Intensive Crops", *Indian Journal of Agricultural Economics*, Vol. 58, No. 3, July-September, pp. 427-437.

Narayanamoorthy, A. (2004), "Drip Irrigation in India: Can it Solve Water Scarcity?", *Water Policy*, Vol. 6, No.2 pp. 117-130.

Narayanamoorthy, A. (2004a), "Impact Assessment of Drip Irrigation in India: The Case of Sugarcane", *Development Policy Review*, Vol. 22, No. 4, pp. 443-462.

Postal, S., Polak, P., Gonzales, F., & Keller, J. (2001), "Drip Irrigation for Small Farmers: A New Initiative to Alleviate Hunger and Poverty", *Water International*, Vol. 26, No. 1.

Postal, S. (1999), *Pillar of Sand: Can the Irrigation Miracle Last?,* W.W. Norton and Company, New York.

Rath, N. and A.K. Mitra (1989), "Economics of Irrigation in Water-Scarce Region: A Study of Maharashtra", *Artha Vijnana*, Vol.31, No.1, March, pp. 1-129.

Rosegrant, W. Mark (1997), *Water Resources in the Twenty-First Century: Challenges and Implications for Action,* Food and Agriculture, and the Environment Discussion Paper 20, International Food Policy Research Institute, Washington D.C., U.S.A., March.

Rosegrant, W. Mark and Ruth S. Meinzen-Dick (1996), "Water Resources in the Asia-Pacific Region: Managing Scarcity", *Asian-Pacific Economic Literature*, Vol.10, No.2, November, pp. 32-53.

Shah, Tushaar (1993), *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy*, Oxford University Press, Delhi.

Shah, T; Roy, A.D; Qureshi, A.S and Wang, J. (2003), Sustaining Asia's Groundwater Boom: An Overview of Issues and Evidence, *Natural Resources Journal*, No. 27, pp. 130-141.

Shah, T; Singh, O.P.; Mukherji, A. (2006), "Some Aspects of South Asia's Groundwater Irrigation Economy: Analyses from a Survey in India, Pakistan, Nepal Terai and Bangaladesh", *Hydrogeology Journal*, No. 14, pp. 286-309.

Sharma, Anil, (1994), "Electricity for Minor Irrigation", *Seminar,* No. 418, June, pp. 21-24.

Sivanappan, R.K. (1994), "Prospects of Micro Irrigation in India", *Irrigation and Drainage System,* Vol.8, No. 1 pp. 49-58.

TERI (2005), *TERI Energy Data Directory and Year Book, 2004-05*, Tata Energy Research Institute, New Delhi, India.

Vaidyanathan, A. (1994), *Food, Agriculture and Water: Second India Studies Revisited*, Madras Institute of Development Studies, Madras, January.

Vaidyanathan, A. (1996), "Depletion of Groundwater: Some Issues", *Indian Journal of Agricultural Economics,* Vol.51, Nos. 1 and 2, January-March, pp.184-192.

Vaidyanathan, A. (1998), *Water Resource Management: Institutions and Irrigation Development in India*, Oxford University Press, New Delhi.

Varma, C.V.J., & Rao, A.R.G. (Eds.) (1998), Micro-*Irrigation and Sprinkler Irrigation Systems*, Central Board of Irrigation and Power, New Delhi.

Varma, C.V.J. and A.R.G. Rao (Eds.) (1998) *Proceedings: Workshop on Micro Irrigation and Sprinkler Irrigation Systems,* Central Board of Irrigation and Power, New Delhi.

World Bank (1991), *INDIA - Irrigation Sector Review,* Report No. 9518-IN, The World Bank, Washington D.C., December.

World Bank (2001), *INDIA – Power Supply to Agriculture*, Report No. 22171-IN, The World Bank, Washington, D.C., June.