[This is a draft paper for discussion. Please do not quote.]

IWMI-Tata Water Policy Program

Annual Partners' Meet 2004

Promoting Micro Irrigation in India:

A Review of Evidence and Recent Developments*

Shilp Verma

The research covered by this paper was carried out with generous support from Sir Ratan Tata Trust, Mumbai under the IWMI-Tata Water Policy Program. This is a pre-publication paper prepared for the IWMI-Tata Annual Partners' Meet, 2004.

* **Based on Research by IWMI-Tata Core Team**

Visit: http://www.iwmi.org/iwmi-tata

ABSTRACT

In the classical model of irrigation efficiency, all water applied to the crop is treated as consumed or lost while the integrated basin view of irrigation efficiency views only the effective evapo-transpiration as the consumptive use in irrigation. In either case, increased water efficiency at farm/individual level would not lead to water saving at the system (basin) level unless these higher farm efficiencies are achieved system-wide! Thus, unless the adoption of micro-irrigation is scaled up, it would not make any significant contribution to alleviating the problem of groundwater depletion and in resolving various related issues. Even after more than three decades of promotion by various government and non-government agencies, the spread of micro-irrigation in India is miniscule. The limited growth of micro-irrigation technologies in India can, to a large extent, be explained by the apparent gap between what has been marketed and where the demand lies. This paper tries to understand the adoption, spread, impacts, market dynamics and constraints of micro-irrigation technologies through an extensive review of literature and by capturing recent development in the field to derive conclusions and implications for promotion of these technologies, especially among the poor.

1.0 INTRODUCTION

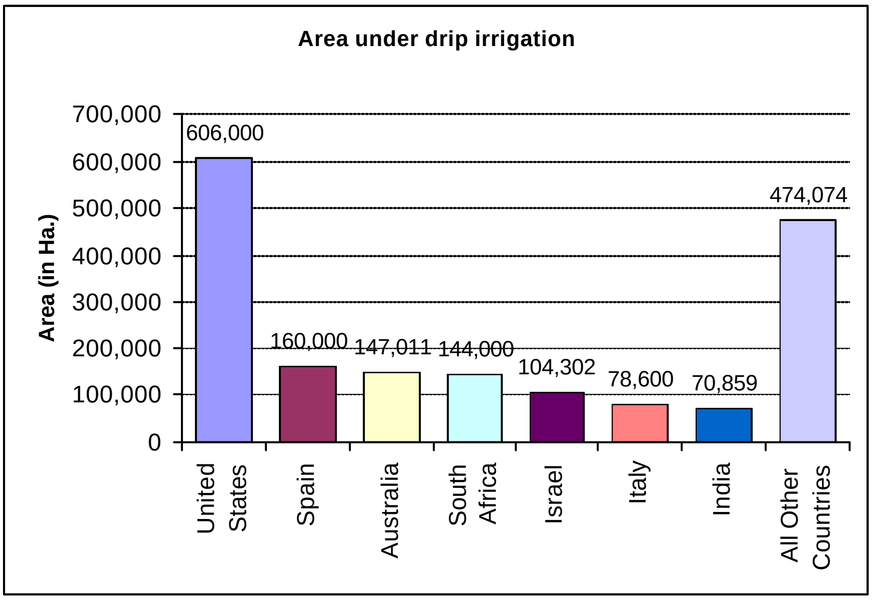
Water scarcity poses serious threats to rural livelihoods and food security. Studies undertaken by the International Water Management Institute (IWMI) (Seckler *et al.*, 1998; Seckler *et al.*, 1999) have estimated that by the year 2025, one-third of the world population will face absolute water scarcity and amongst the worst hit areas would be the semi-arid regions of Asia, the Middle East, and Sub-Saharan Africa which is home to some of the largest concentrations of world poverty. Absolute scarcity and the tempo-spatial variability in water availability necessitated technological, institutional and policy interventions of various sorts to enable the equitable and sustainable use of water. One of the technological interventions in agriculture espoused to have substantial impact on water use efficiency is micro-irrigation / precision-irrigation technologies. Precision Irrigation refers to a broad range of technologies and water management practices that enable farmers to use their limited water resources in a manner that increases the productivity of water (Sally *et al.*, 2000).

Drip irrigation (in its various forms – Conventional drip systems, Indigenous pot drips, Sub-surface drips, Bucket drip kits, Micro-tubes, Easy Drip, Family drip kits and locally manufactured and assembled kits like *Pepsee*) is amongst the most popular modes of micro-irrigation in India. Drip irrigation is a technology through which water is applied directly at the root zone of the plants leading to significant reduction in conveyance and application losses compared to the conventional flood irrigation method. The benefits of drip-irrigation technologies in water scarce regions have been widely studied all over the world. A review of evidences from several studies on drip-irrigation technologies strongly suggests significant financial, economic and social benefits of the technologies. However, the spread of these technologies; their adoption and diffusion have been far below potential and expectations. This paper tries to understand the adoption, spread, impacts, market dynamics and constraints of drip technologies and to derive conclusions and implications for promotion of these technologies, especially among the poor.

2.0 GENESIS AND GLOBAL OUTLOOK

Micro irrigation concepts date back to as early as 1917. Originally developed in England, Denmark, Germany, New Zealand and America for irrigating greenhouse crops, drip irrigation became a commercially viable technology only after the advent of inexpensive, weather-resistant polyethylene plastics post World War II in Australia and Israel (Wolff, 1987; Roberts and Styles, 1997; Postel *et al*., 2001). The pioneers of this technology were Mr. Hansen in Denmark, Mr. Blass in Israel and Mr. Chapin in the United States (Chapin, 2000). Modern drip irrigation has now reached an area of close to two million hectares (Polak *et al*., 1997a; Polak *et al*., 1997b). Globally, the United States leads in area under micro-irrigation technologies, followed by Spain, Australia, South Africa and Israel (Figure I; INCID, 1994).

Figure I: Area under drip irrigation – Global Scenario (1991)



Data Source: INCID, 1994

3.0 POTENTIAL AND SPREAD OF DRIP IRRIGATION IN INDIA

In order to meet the food grain consumption demand and some surplus amount for export, India will need to produce not less than 500 million tonnes by 2050 (Government of India, 2001). While expanding the area under irrigation is one option, it is becoming increasingly expensive (Naralawala, 1992) and there is a limit to this expansion. The total potential utilisable volume of water in India is estimated to be around 105 million hectare meters (MHM) and even with full exploitation of this potential, a little less than 50 percent of India's cultivated area will remain rain fed (Sivanappan, 1988; Sivanappan, 1994). Under such resource constraints, more efficient use of available land and water resources will be an important means to expand irrigation benefits (Government of India, 1995; Dhawan, 1995; Saleth, 1996). Thus, the development of reliable low cost water saving technologies has long been recognized as a critical need in developing countries such as India (Hillel, 1985; Saksena, 1995; Nir, 1995).

In India, drip irrigation technologies arrived in the 1970s from developed countries like Israel and the USA, where the technology is widely used by big commercial farmers. Preliminary research studies showed that other than water saving, the yields of crops using drip irrigation are substantially higher that crops irrigated by flood method of irrigation (Narayanamoorthy, 1996b; Narayanamoorthy, 1997b; INCID, 1994; Magar *et al.*, 1998; Kulkarni, 1987). The Government of India, realizing the potential, released Rs. 11.96 crores to state governments under centrally sponsored schemes between 1982-83 and 1991-92, for the promotion of drip, sprinkler and other water saving irrigation systems and practices (Narayanamoorthy and Deshpande, 1997; 1998). However, since they were first introduced, the total area under drip irrigation has expanded rather sluggishly from 1500 ha in 1985 to a little over 70,000 ha in 1992 (Chakravarty and Singh, 1994; Narayanamoorthy, 1997a) and rapid growth has only been seen in recent years as the area spread to 225,000 ha in 1998 (Polak and Sivanappan, 1998) which is still very low compared to an estimated potential of 10.50 million ha (Sivanappan, 1994).

Maharashtra leads the tally of area under drip irrigation covering almost half the total area, followed by Andhra Pradesh, Karnataka and Tamil Nadu (Figure II; Kannan and Gurumurthy, 1999; Kareem, 1999). In terms of crop-wise distribution, almost half the area under drip irrigation is orchards and another significant portion under plantation crops (Figure III; Kannan and Gurumurthy, 1999).The technology is most popular among citrus and orange orchards and in grapes in Maharashtra; coconut in Coimbatore, Tamil Nadu and mulberry in Kolar, Karnataka (Shah and Keller, 2002).

Figure II: State wise area under drip irrigation

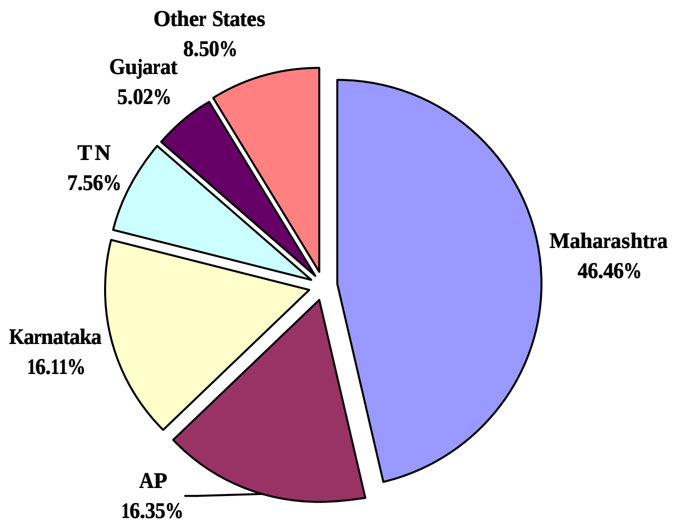
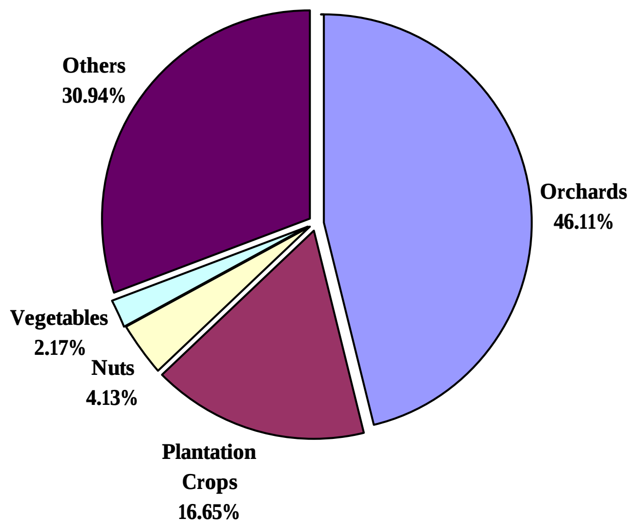


Figure III: Crop wise area under drip irrigation



Data Source: Kannan and Gurumurthy, 1999

4.0 IMPACT STUDIES

Drip irrigation is widely recognised as one of the most efficient methods of irrigation (Keller and Blisner, 1990). Generally, drip irrigation is said to cut down the water use by 30-70 percent and increase the yields by 20-90 percent (Postel, 1999; Suryawanshi, 1995; World Bank, 1993). Sivanappan (1994) suggests that micro irrigation reduces water application by 40-70 percent and raises crop yields by 200 percent for many crops. In a survey of 100 farmers in Maharashtra, Narayanmoorthy (1996b; 1997a; 1997c) found that drip irrigation cuts cost of cultivation especially in inputs like fertilizers, labour, tilling and weeding. In another study, Narayanamoorthy (1996a; 1997b) estimated that drip irrigation reduces the consumption of water by 41 percent and 59 percent in banana and grapes cultivation respectively. Drip irrigation thus saves about 30-70 percent of water compared to flood irrigation and at the same time; appropriate application of fertilizer and other inputs in combination with drip system of irrigation have the potential to raise land productivity by 100 percent. This will also economize use of fertilizer by about 30-40 percent. Additional advantages of drip irrigation include reduction in weed growth, better quality yield, less labour requirement, less electric power consumption, early maturity of crops and applicability even with the use of mildly saline water.

The tables below show the results of various studies done on a variety of crops to measure yields, water supplied and water productivity under drip irrigation as compared to conventional (surface water use, furrow and flood) methods of irrigation. Table I compares yields and water supplied for eight crops under drip and conventional irrigation systems. The data compiled by the National Committee on the Use of Plastics in Agriculture (NCPA, 1990) shows 23-88 percent increase in crop yields and 36-68 percent saving in water supplied. Table II is a compilation of results from various research publications and compares water saving, yields and water use efficiency (measured as kg/ha. mm.) under drip and traditional methods of irrigation for ten crops. The results show 13.49-69.47 percent increase in yields and 25.00-79.34 percent water saving. Table III is a compilation from Postel (1999) and is based on research results from INCID (1994) and Sivanappan (1994). The table compares results for eight crops and shows up to 52 percent increase in yields and up to 65 percent water saving. It also shows that there are significant increments in water productivity through the adoption of drips in the range 46-255 percent. Finally, Table IV is a compilation of similar results from different research stations in India for sixteen crops and shows yield benefits of up to 77 percent and water saving of up to 80 percent through the adoption of drip irrigation systems.

Table I: Yields and Water Use for Selected Crops under Conventional and Drip Irrigation Systems

Crop	Yield (Quintal/Ha)			Water Supplied (cm.)		
	Conventional	**Drip**	**Increase**	**Conventional**	**Drip**	**Saving**
Banana	575.00	875.00	52%	176.00	97.00	45%
Grapes	264.00	325.00	23%	53.20	27.80	48%
Sugarcane	1280.00	1700.00	33%	215.00	94.00	65%
Tomato	320.00	480.00	50%	30.00	18.40	39%
Watermelon	240.00	450.00	88%	33.00	21.00	36%
Cotton	23.30	29.50	27%	89.53	42.00	53%
Chillies	42.33	60.88	44%	109.71	41.77	62%
Papaya	13.40	23.48	75%	228.00	73.30	68%

Source: NCPA, 1990

Table II: Water Saving, Yields and Water Use Efficiencies for Various Crops under Surface Irrigation, Furrow Irrigation and Drip Irrigation Systems in India.

Crop	Method	Water Saving	Increase in Yield	Water Use Efficiency (Kg/ha. mm.)
Cotton	Drip	66.27%	25.00%	116.10
	Furrow	-	-	31.33
Sugar beet	Drip	25.05%	17.09%	1320.00
	Furrow	-	-	850.00
Sweet potato	Drip	60.06%	38.73%	233.65
	Surface	-	-	67.26
Beetroot	Drip	79.34%	55.34%	50.11
	Surface	-	-	6.66
Radish	Drip	75.72%	13.49%	109.80
	Surface	-	-	22.52
Papaya	Drip	67.89%	69.47%	0.32
	Surface	-	-	0.06
Mulberry	Drip	60.00%	3.03%	3750.00
	Surface	-	-	1386.00
Coconut	Drip	48.00%	19.00%	-
	Traditional	-	-	-
Mango	Drip	25.00%	33.00%	-
	Traditional	-	-	-
Sapota	Drip	25.00%	31.00%	-
	Traditional	-	-	-
Banana	Drip	29.16%	29.10%	-
	Flood	-	-	-

Grapes	Drip	37.28%	19.07%	-
	Flood	-	-	-

Source: Cotton: Sivanappan et al., 1987; Sugar beet: Agarwal and Goel, 1981; Sweet potato, Beetroot and Radish: Sivanappan and Padmakumari, 1980; Papaya: Sivanappan, 1977; Mulberry: Muralidhara et al., 1994; Coconut, Mango and Sapota: Paul and Sharma, 1999; Banana and Grapes: Narayanamoorthy, 1999.

Table III: Water Productivity Gains from Shifting to Drip from Conventional Surface Irrigation in India (Results from various Indian Research Institutes).

Crop	Change in Yield	Change In Water Use	Change in Water Productivity (Crop Yield/Unit of Water Supplied)
Banana	+52%	-45%	+173%
Cabbage	+2%	-60%	+150%
Cotton	+27%	-3%	+169%
Cotton	+25%	-60%	+255%
Grapes	+23%	-48%	+134%
Potato	+46%	~0	+46%
Sugarcane	+6%	-60%	+163%
Sugarcane	+20%	-30%	+70%
Sugarcane	+29%	-47%	+91%
Sugarcane	+33%	-65%	+205%
Sweet potato	+39%	-60%	+243%
Tomato	+5%	-27%	+49%
Tomato	+50%	-39%	+145%

Source: Postel, 1999; based on data from INCID, 1994 and Sivanappan, 1994.

Table IV: Comparative Advantage of Drip Irrigation over Flood Irrigation: Results from Different Research Sations.

Research Institute	Crop	Water Saving	Yield Increase
MPAU, Rahuri	Sugarcane	30.0%	20.0%
TNAU, Coimbatore	Sugarcane	47.0%	29.0%
MPAU, Rahuri	Cotton	43.0%	40.0%
TNAU, Coimbatore	Cotton	79.0%	25.0%
MPAU, Rahuri	Tomato	30.0%	5.0%
TNAU, Coimbatore	Lady Finger	84.0%	13.0%
MPAU, Rahuri	Brinjal	47.0%	-
MPAU, Rahuri	Chilli	62.0%	44.0%
TNAU, Coimbatore	Radish	77.0%	13.0%
TNAU, Coimbatore	Beet	80.0%	56.0%
TNAU, Coimbatore	Sweet Potato	61.0%	40.0%
HAU, Hissar	Potato	-	46.0%
HAU, Hissar	Onion	-	31.0%
TNAU, Coimbatore	Banana	77.0%	-
TNAU, Coimbatore	Papaya	68.0%	77.0%
Jyoti Ltd., Vadodara	Lemon	81.0%	35.0%
Jyoti Ltd., Vadodara	Groundnut	40.0%	66.0%
Jyoti Ltd., Vadodara	Coconut	65.0%	12.0%

Source: Narayanamoorthy, 1999; compiled from INCID, 1994.

Notes: MPAU – Mahatma Pule Agricultural University; TNAU – Tamil Nadu Agricultural University; HAU – Haryana Agricultural University.

There also exist numerous studies on the initial investments required for drip irrigation and the Benefit-Cost (B-C) ratios for the investment. Table V (Narayanamoorthy, 1999) lists the capital costs and B-C ratios for nine different crops with varying spacing. The costs range between Rs.11,000 and Rs.33,000 per hectare. These costs are for the conventional drip irrigation systems. Other less expensive systems are also available in the market including International Development Enterprises' (IDE's) bucket kits, Netafim's Family drip kits, Easy drip and farmer manufactured and assembled kits such as *Pepsee*. The B-C ratios vary from 2.78 to 32.32. Similarly, Table VI (Reddy and Reddy, 1995) provides capital costs and B-C ratios for twelve horticulture crops and here the costs are much higher. The capital costs range between Rs.67,000 and Rs.293,500. The B-C ratios range between 1.08 and 4.23.

Table V: Benefit cost ratio of different drip irrigated crops.

Crop	Spacing (m x m)	Capital Cost (Rs/ha)	Benefit Cost Ratio	
			Excl. Water Saving	Incl. Water Saving
Coconut	7.62 x 7.62	Rs.11,053.00	1.41	5.14
Grapes	3.04 x 3.04	Rs.19,019.00	13.35	32.32
Grapes	2.44 x 2.44	Rs.23,070.00	11.50	27.08
Banana	1.52 x 1.52	Rs.33,765.00	1.52	3.02
Orange	4.57 x 4.57	Rs.19,859.00	1.76	6.01
Pomegranate	3.04 x 3.04	Rs.19,109.00	1.31	4.40
Mango	7.62 x 7.62	Rs.11,053.00	1.35	8.02
Papaya	2.13 x 2.13	Rs.23,465.00	1.54	4.01
Sugarcane	b/w bi-wall 1.86	Rs.31,492.00	1.31	2.78
Vegetables	b/w bi-wall 1.86	Rs.31,492.00	1.35	3.09

Source: Narayanamoorthy, 1999; compiled from INCID, 1994.

Table VI: Benefit cost ratio of various horticultural crops under trickle irrigation system.

Crop	Spacing (m x m)	Capital Cost (Rs/ha)	Benefit Cost Ratio
Mango	10 x10	Rs.67,150.00	1.30
Oil Palm	9 x 9	Rs.80,300.00	1.72
Coconut	8.2 x 8.2	Rs.66,850.00	1.08
Sapota	7.6 x 7.6	Rs.62,655.00	2.07
Guava	6.1 x 6.1	Rs.72,133.00	1.55
Ber	6.1 x 6.1	Rs.67,139.00	1.56
Citrus	6.1 x 6.1	Rs.75,802.00	1.99
Grapes (Anab-e-shahi)	4.6 x 4.6	Rs.250,350.00	1.68
Grapes (Thompson Seedless)	4.6 x 4.6	Rs.293,500.00	1.57
Pomegranate	4.3 x 4.3	Rs.84,500.00	4.23
Coccima India	3 x 3	Rs.132,550.00	1.11
Rose	1.2 x 1.2	Rs.168,400.00	3.08

Source: Reddy and Reddy, 1995

In a survey of 180 farmers in Maikaal, Verma, *et al*. (2003) found that while drip irrigation did lead to significant water savings at the individual farm level, these savings are only '*notional*' and the total water extracted from the aquifers might have gone up as farmers increased area under irrigation and other farmers who could not irrigate their fields without drip irrigation also started extracting water.

The calculations shown in the tables above indicate significant benefits from the adoption of drip irrigation technologies. However, these figures suffer from three kinds of deficiencies:

[1] Most of the data in the tables is based on results from experimental plots and not on measurements in actual farmer fields, where the conditions and therefore the results are much different;

[2] The limited number of studies which do talk about data from farmer fields are based on respondent surveys and not on actual measurements. It has been found that these results are highly variable in nature and not very reliable; and

[3] All the calculations (except in the case of Verma *et al*. 2003) do not take into account the difference between improved water use efficiencies at farm level and real water saving.

Under IWMI's unique experiment in north Gujarat (North Gujarat Sustainable Groundwater Initiative – NGI), it was found that one farmer who reported 70% saving in water use during one survey, reported 20-30% saving in another survey a few days later! On actual measurement, both the figures were found to be incorrect (Kumar, 2003: Personal Communication). Dhawan (2000) critiques Narayanamoorthy (1997) saying that it takes into account only direct costs and returns, instead of incremental costs and returns; in which case, the Benefit-Cost ratios would drop drastically. Similar issues were identified by Dhawan (2000) with Sivanappan's (1994) study where the author is assuming that the saved water would be put to use. With this, the B-C ratio increased manifold.

Again, there are significant issues regarding what is meant by 'water saving'? For the farmer who adopts micro-irrigation, it means greater efficiency in use of water; for the scientist in the research plot, it means less water requirement to irrigate the same cropped area without negatively affecting the yields. But, does that get translated to water saving at the basin level? None of the literature reviewed here seems to have any answer to this. Most authors seem to use 'water saving' and 'improved water use efficiency' to mean the same thing. However, when micro-irrigation is seen as a solution to the groundwater depletion problem, this creates problems.

To conclude, while it has been well established that micro-irrigation technologies would lead to improved water use efficiency, both in the field as well as in research plots; there is still ambiguity about its impact on groundwater draft.

5.0 SUBSIDIES, ADOPTION AND MARKET DYNAMICS

Given the many persuasive arguments in favour of drip irrigation system, convincing financial and economical viability and the subsidies provided by the Government of India, one would have expected large-scale adoption of drip irrigation systems by farmers. This expectation, however, has so far been belied, as the drip-irrigated area is much less than one percent of total groundwater – irrigated area (Dhawan, 2000). Despite active promotion by a growing private irrigation equipment industry and subsidies provided by governments, the appeal of these technologies has remained confined to "gentlemen farmers" (Shah and Keller, 2002). The main reasons for the sluggish growth, as identified by several research papers, are: [1] high initial capital investment; [2] lack of credit facilities; and [3] lack of information.

A buried strip drip system in the USA costs about US$1,200 per acre (about the market value of an acre of irrigated land in India) and will last 5-10 years and requires low-till, high herbicide agriculture (Electronic Comm., David Seckler). In a survey of 160 farmers in Nagpur, Puranik *et* *al*. (1992) found that all the farmers found the high capital cost to be the biggest barrier to adoption.

Efforts have been made to reduce the initial investments required by both government as well as private agencies. The government has provided numerous subsidies to allow poor farmers to adopt these technologies. However, there are conflicting views on whether the subsidies have indeed helped in promoting the technologies or in hindering their growth. Shah and Keller (2002) point out that the subsidy regime actually encouraged spurious players to enter the market and benefit from the government subsidies. This lead to a decline in quality of equipment available in the market and actually hindered the growth of drip technologies. They also point out that major industry players, like Jain Irrigation, got frustrated by the distortions caused by the subsidies and the unfair competition from shady players who sell low-quality products, and often claim subsidies without selling the drip systems.

Several private players have also done their bit in promoting drip technologies. The International Development Enterprises (IDE) has developed low cost drip irrigation systems (drum kits, bucket kits etc) for poor farmers which cost less than US $250 per hectare (Polak *et al.*, 1997a; 1997b). Netafim has also come out with 'family drip kits', essentially targeted at small farmers. One of the biggest strides in this direction has been the popularity of *Pepsee* systems in Maikaal. Farmers in the Maikaal region have, in *Pepsee* found an economical and productive way to reduce their water requirements in agriculture (Verma *et al.*, 2003). In 2001, IDE India has recognized the success of this grassroots innovation and has come up with its own version of the Pepsee, aptly named 'Easy Drip', targeted largely at vegetable growing farmers.

The strategy for promotion of water efficient technology has to be woven around "yield increase" and "higher farm returns" rather than "water saving" (Umesh and Kumar, 2003). Costly pressurised irrigation systems would find greater acceptance among resource rich, large farmers who are not able to irrigate entire command due to water scarcity and farmers who are not able to utilise power supply fully (Kumar, 2003). Innovative solutions such as *Pepsee* and Easy Drip would best address the needs of small and poor farmers. The limited growth of micro-irrigation technologies in India can, to a large extent, be explained by the apparent gap between what has been marketed and where the demand lies (Verma, 2003).

6.0 GAPS IN LITERATURE

While reviewing evidences available on micro-irrigation technologies and their adoption, some of the knowledge gaps identified are as below:

1 Social cost benefit ratio estimates are conspicuously missing from micro irrigation literature in India. This observation is also explicitly made by Dhawan (2000). Most literature talks about financial or, at best, economic costs and benefits of adoption of these technologies.
2 Most of the calculations are based on experimental field trials undertaken by numerous research institutes and are not based on empirical data from the farmers' fields. The survey of 180 farmers in Jalgaon and West Nimar (Verma *et al.*, 2003) and a few other studies including Umesh and Kumar 2003 and Kumar *et al* in north Gujarat, Puranik *et al.* 1992 in Nasik and surveys by Narayanamoorthy in Maharashtra and Tamil Nadu (Narayanamoorthy and Deshpande, 1997, 1998; Narayanamoorthy, 1996a, 1996b, 1997a, 1997b, 1997c) are a few notable exceptions.
3 Most researchers justify investments in micro irrigation technologies through calculations of Net Present Value (NPV), Internal Rate of Return (IRR) and Pay Back Period. These, often have very little to do with small farmer investment decisions.

4 Studies make little or no attempt to determine if adoption of micro irrigation technologies can have a positive impact at the system (basin/sub-basin) level in terms of water saving and alleviating groundwater depletion. All the studies point to farm level savings in water, which might actually be only *notional* savings. Micro irrigation technologies are often termed as 'Water Saving' technologies. Whether these can actually help in alleviating the problem of groundwater over-extraction is not implicit.

5 The nexus between energy availability and pricing; pumping behavior and micro-irrigation adoption in groundwater irrigation has largely been ignored and needs to be explored in detail.

7.0 POLICY IMPLICATIONS

Over the years, government as well as various non government agencies have been promoting micro-irrigation as a 'New Concept in Agriculture' through a "Package Solution" with the following salient features: [1] Water Saving; [2] Positive Net Present Value (NPV); [3] Good Pay Back Period and Internal Rate of Return (IRR); [4] Customized and Highly Sophisticated Technology; [5] Higher Yields and Better Quality of Output; and [6] Labour Saving (Verma, 2003).

The farmers, on the other hand, have different priorities and concerns. They demand solutions and technologies that would provide them: [1] Assured Returns; [2] Lower Costs; [3] Simple Technology; [4] Generic Applicability; and [5] Higher and better Yields with fewer pumping hours (Verma, 2003). Hence, there are obvious gaps between what the market demands and what the industry has to offer. This gap can be bridged by: [1] **shifting from "water saving" to "income enhancing" mode**; [2] **shifting micro-irrigation technologies from investment mode to input mode**; [3] **proving special incentives for "first movers"**; and [4] **from custom-made solutions or package kits to farmer-assembled systems**. In fact, some of these shifts can already be seen. IDE promoted low-cost micro-irrigation systems have expanded the market for these technologies. Even Netafim, the largest irrigation company in the world, has recognised this trend and their Indian subsidiary, Netafim India Ltd. has launched a product, named, Family Drip System, which consists of online drippers, designed for small plots of size 500 m^2. This system requires very little pressure to run and is also claimed to be suited to situations without individual pressurizing devices (Kumar *et al.*, Forthcoming). The almost un-induced spread of *Pepsee* systems in Maikaal in central India is another case in point. It exemplifies the need to shift from technologies that operate on the "high initial investment – returns over number of years" principle to "micro irrigation as a yearly investment" mode.

[1] **Shifts from 'Water Saving' to 'Income Enhancing' Technologies:** Micro-irrigation technologies are almost always marketed as 'water saving' technologies. However, unlike several academicians and scientists, farmers do not like to take the burden of environmental sustainability on their already tiring shoulders. Their concern is to protect, sustain and enhance their livelihoods.

[2] **Shifting Water Saving Technologies from Investment Mode to Input Mode:** There is a need to view water saving technologies as recurring but much lower input costs rather than capital investments that offer returns over the next 8-10 years. If the small farmers are to be targeted, policy makers must understand that they would be hesitant in making huge-capital investments in new technologies unless they are very sure of their results. Even when they are convinced about the returns, they might not be in a position to incur the huge capital costs due to poor access to good quality credit options.

[3] **Creating 'First Mover Advantage':** Unlike in the case of pump technology, where being the first adopters meant that one could skim the market by selling water to other, there do not seem to be any apparent first mover advantages in the adoption of micro-irrigation. Almost each farmer would tend to wait for others in the village or neighbourhood to try out and test the new technologies first and prove to all, at their risk, the reliability of the technologies. In such a scenario, it makes sense to provide special incentives to 'first movers'. This can and is already being done in two ways. One way, as being done in IWMI's North Gujarat Initiative in Banaskantha, is to create demonstration plots in the area and let the farmers see for themselves what works and what does not. This will also help in exposing the farmers to several types of micro-irrigation technologies. Two, as is being done by AKRSP (I) in Saurashtra, is to provide higher subsidies to first adopters and gradually reduce the amount of subsidies over the years and with expansion.

[4] **From Custom-Solutions to a Package Solution to Farmer-Assembled Systems:** The market for Micro Irrigation products is experiencing its second major shift today. From the highly sophisticated custom built drip irrigation solutions for the large farmers, the technology shifted towards Package Solutions provided in the form of Drip-Kits popularised by IDE in the form of Bucket-Drip-Kits and Micro-Tube-Kits and the recent Family-Drip-Kits being offered by Netafim. Today, there is a need to transfer the technology into the hands of the users. The farmers are demanding components of drip-kits like pipes, drippers etc which they can assemble on their own and the biggest example of this shift is the popularity of *Pepsee* systems.

There are also a few other experiments being tried out which are worth noting. The Aga Khan Rural Support Program (India) [AKRSP (I)] is involved in the promotion of micro irrigation technologies in Saurashtra, India. Instead of providing subsidies to farmers, which is the traditional way of providing incentives for purchase, they have supported private entrepreneurs to set-up manufacturing plants locally. Initial results from this experiment have been very positive and such models, if found successful, need to be replicated aggressively. IWMI itself has set up an experiment in north Gujarat – an action research project in Banaskantha district – to facilitate large scale adoption of water saving technologies. The fountainhead of IWMI's strategy in north Gujarat has been to manipulate the demand for water in agriculture without compromising on the net returns from agriculture, so as to cut down groundwater pumping (Kumar *et al*. Forthcoming). NGI promotes the adoption of micro-irrigation technologies and also creates demonstrations of micro-irrigation in north Gujarat. However, unless these technologies are adopted at a significant scale, their impact on sustainability of groundwater irrigation might not be meaningful. Farmers who adopt micro-irrigation might use the 'saved' water to increase their area under irrigation or to sell excess water to the non-pump owners. Moreover, even if total pumping by a few farmers reduces in absolute terms, it would mean better water availability to all farmers (including non-adopters) and the basin level pumping might not reduce.

There is also a strong need to try out these technologies in more crops. At present, more than 60 percent of the area under drip irrigation can be attributed to orchids and plantation crops. The challenge lies in popularising these technologies in major crops such as wheat, groundnut, alfalfa etc. One of the ways of doing this is through control plot experiments in research laboratories, but another and possibly more fruitful way would be to transfer the technology innovation process to the farmers' own land. If the technology is suitably de-mystified and successfully transferred to the farmers, newer avenues of its application would crop up on their own.

REFERENCES

Agarwal, M. C. and Goel, A. C., 1981, Yield, quality and water use efficiency for vegetable crops under drip and surface methods, in Proceedings of First National Seminar on Drip Irrigation, Tamil Nadu Agriculture University, Coimbatore, pp. 39-49.

Chakravarty, S. and Singh, L. B., 1994, Water economy through drip irrigation, in Proceedings of the 20th WEDC Conference, Colombo, Sri Lanka. [http://www.lboro.ac.uk/departments/cv/wedc/papers/20/sessiong/chakrava.pdf]

Chapin, R. D., 2000, A worldwide problem – "Drip irrigation vs. Relief food" – An Update, Chapin Living Waters Foundation, New York, USA. [http://lnweb18.worldbank.org/essd/essd.nsf/a95275735facede4852569970057eeb2/892fc2814aca1782852569fb004d4710/$FILE/ChapinOrlandoPaper.doc]

Dhawan, B. D., 1995, Magnitude of groundwater exploitation, *Economic and Political Weekly*, Vol. 30, No. 14, April 8, pp. 769-775.

Dhawan, B. D., 2000, Drip irrigation: Evaluating returns, *Economic and Political Weekly*, October 14, pp. 3775-3780.

Government of India, 1995, Water Related Statistics, Central Water Commission, Ministry of Water Resources, New Delhi.

Government of India, 2001, Report of the Working Group on Minor Irrigation for formulation of the Tenth Five Year Plan (2002-2007) Proposals, Minor Irrigation Division, Ministry of Water Resources, New Delhi. [http://www.planningcommission.nic.in/aboutus/committee/wrkgrp/wrkg_minor.pdf]

Hillel, D., 1985, Status of Research in Drip/Trickle Irrigation, in Proceedings of the Third International Drip/Trickle Irrigation Congress, Fresno, C.A. USA, Nov., pp. 18-21.

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

Kannan, S. and Gurumurthy, S., 1999 Drip irrigation and water management, *Yojana*, Feb., pp. 15-16.

Kareem, A. A., 1999, Micro-irrigation: Need of the 21st century for conserving water resources, in ICID, 17th Congress on Irrigation and Drainage, Granada, Spain, 1999: Water for Agriculture in the Next Millennium - Transactions, Vol.1D, New Delhi, India. pp. 21-37.

Keller, J. and Blisner R.D., 1990, Sprinkler and trickle irrigation, Chapman and Hall, New York, USA.

Kulkarni, S. Y., 1987, Sprinkler and drip irrigation system, *Sinchan*, Vol. 6, No. 3, Oct., pp. 56-61.

Kumar, M. D., 2003, *Personal communication and e-mail discussion*. Project Director, North Gujarat Sustainable Groundwater Initiative (NGI), International Water Management Institute, Anand.

Kumar, M. D., Shah, T., Bhatt, M. and Kapadia, M., Forthcoming, Dripping Water to a Water Guzzler: A Techno-Economic Evaluation of the Efficiency of Drip Irrigation in Alfalfa, International Water Management Institute, Anand.

Kumar, M. D., 2003, Micro-management of groundwater: IWMI's experiment in north Gujarat; Paper presented at the 3rd World Water Forum; in "Groundwater Governance in Asia: The challenge of taming a colossal anarchy", Booklet published for the 3rd World Water Forum, International Water Management Institute, India.

Magar, S. S., Firke, N. N. and Kadam, J. R., 1988, Importance of drip irrigation. *Sinchan*, Vol. 7, No. 2, Oct., pp. 61-62.

Muralidhara, H. R., Gundurao, D. S., Sarpashkar, A.M. and Ramaiah, R., 1994, Is drip irrigation viable for mulberry cultivation – An economic analysis. *Mysore Journal of Agriculture Science*, Vol. 28. pp. 256-266.

Naralawala, B. N., 1992, Economic aspects of irrigation and pricing of water, in Proceedings of the seminar on Irrigation Water Management, New Delhi.

Narayanamoorthy, A. and Deshpande, R. S., 1997, Efficient water management through drip irrigation: Some evidences from Western India, in ICID, The Tenth Afro-Asian Regional Conference Proceedings: Water and land resources development and management for sustainable use, Denpasar, Bali, Indonesia, 19-24 July.

Narayanamoorthy, A. and Deshpande, R. S., 1998, 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, Maharashtra.

Narayanamoorthy, A., 1996a, Impact of drip irrigation on consumption of water and electricity. *The Asian Economic Review*, Vol. 38, No. 3, Dec., pp. 350-364.

Narayanamoorthy, A., 1996b, Evaluating drip irrigation system in Maharashtra, *Artha Vignana*, VXXXVIII N 1, Mar. pp. 97-114.

Narayanamoorthy, A., 1997a, Economic Viability of drip irrigation: An emphirical analysis from Maharashtra, *Indian Journal of Agricultural Economics*, Vol. 52, No. 4, Oct.-Dec.

Narayanamoorthy, A., 1997b, Drip irrigation: A viable option for future irrigation development, *Productivity*, Vol. 38, No. 3, Oct.-Dec., pp. 504-511.

Narayanamoorthy, A., 1997c, Beneficial impact of drip irrigation: A study based on western India, *Water Resources Journal*, Vol. 195, pp. 17-25.

Narayanamoorthy, A., 1999, Drip irrigation for sustainable agriculture, *Productivity*, Vol. 39, No. 4, Jan-Mar, pp. 672-678.

National Committee on the Use of Plastics in Agriculture (NCPA), 1990, Status, potential and approach for adoption of drip and sprinkler irrigation systems, Pune.

Nir, D., 1995 Introduction of Pressure Irrigation in Developing Countries, in F. J. R. Lamm (ed.), Proceedings of the Fifth International Micro Irrigation Congress, Orlando, Florida, pp. 442-445.

Paul, J. C. and Sharma, S.D., 1999, Micro-irrigation for water scarce areas of Orissa, *Kurukshetra*, Jun, pp. 27-30.

Polak P. and Sivanappan R. K., 1998, The Potential Contribution of Low Cost Drip Irrigation to the Improvement of Irrigation Productivity in India, India - Water Resources Management Sector Review, Report on the Irrigation Sector. The World Bank in Cooperation with the Ministry of Water Resources, Government of India.

Polak, P., Nanes, B., and Adhikaria, D., 1997a, The IDE low cost drip irrigation system, *Journal of Applied Irrigation Science*, Vol. 32 (1), pp. 105-112.

Polak, P., Nanes, B., and Adhikaria, D., 1997b, A low cost drip irrigation system for small farmers in developing countries, *Journal of the American Water Resources Association*, Vol. 33, No. 1, Feb.

Postel S., 1999, Pillar of Sand: Can The Irrigation Miracle Last?, World Watch, New York, W.W. Norton & Company.

Postel, S., Polak, P., Gonzales, F. and Keller, J., 2001, Drip irrigation for small farmers: A new initiative to alleviate hunger and poverty, *Water International*, 26(1), pp. 3-13.

Puranik, R. P., Khonde, S. R., and Ganorkar, P. L., 1992, Constraints and problems as perceived by non adopters and adopters of drip irrigation systems, *Agricultural Situation in India*, Vol. XLVII, No. 1, Apr. pp. 33-34.

Reddy, K. S. and Reddy G. P., 1995, Micro irrigation for water scarce areas, *Yojana*, Vol 39, No. 8, Jun. pp. 39-42.

Roberts, J. C., Styles, S. W., 1997, Drip irrigation technology: A resource management tool for farmers, *Irrigation Journal*, 47(7), pp. 14-16.

Saksena, R. S., 1995, Micro irrigation in India – Achievement and Perspective, in F. J. R. Lamm (ed.), Proceedings of the Fifth International Micro Irrigation Congress, Orlando, Florida, pp. 353-358.

Saleth, R. Maria, 1996, Water institutions in India: Economic, Law and Policy, Commonwealth Publishers, New Delhi.

Sally H., Sakthivadivel, R., and Molden, D., 2000, More crop per drop: Considerations for precision irrigation in a basin context, Paper presented at the 6th International Micro-Irrigation Congress, "Micro-irrigation Technology for Developing Agriculture", Capetown, South Africa, 22-27 October 2000. 10p.

Seckler, D (2003). Personal communication over e-mail, Ex-Director General, International Water Management Institute.

Seckler, D., Baker, R., and Amarasinghe, U. A., 1999, Water scarcity in the twenty-first century, *International Journal of Water Resources Development*, Special Double Issue: Research from the International Water Management Institute (IWMI), 15 (1/2), pp. 29-42.

Seckler, D., Amarasinghe, U., Molden, D., de Silva, R, and Baker, R., 1998, World water demand and supply, 1990 to 2025: Scenarios and issues, Research Report 19, Colombo, Sri Lanka. International Water Management Institute (IWMI).

Shah, T. and Keller, J., 2002, Micro-irrigation and the poor: A marketing challenge in smallholder irrigation development, in H. Sally and C. L. Abernethy (ed.), Private irrigation in Sub-Saharan Africa: Regional Seminar on Private Sector Participation and Irrigation Expansion in Sub-Saharan Africa, Accra, Ghana, 22-26 Oct. 2001, pp.165-183.

Sivanappan, R. K., 1977, Sprinkler and drip irrigation, *Indian Farming*, 27(2), pp. 23-24.

Sivanappan, R. K., 1988, Use of plastics in drip irrigation, *Moving Technology*, 3(4), Aug. pp. 7-9.

Sivanappan, R. K., 1994, Prospects of micro-irrigation in India, *Irrigation and Drainage Systems*, No. 8, pp. 49-58.

Sivanappan, R. K. and Padmakumari, O., 1980, Drip irrigation, Tamil Nadu Agriculture University, Booklet, pp. 70.

Sivanappan, R. K., Padmakumari, O. and Kumar, V., 1987, Drip irrigation, Keerthi Publishing House (P) Ltd., Coimbatore.

Suryawanshi S. K., 1995, Success of Drip in India: An Example to the Third World, in F. Lamm (ed.), Microirrigation for Changing World, Proceedings of the Fifth International Microirrigation Congress, St Jospeh, MI, American Society of Agricultural Engineers.

Umesh, R. and Kumar M. D., 2003, When farmers adopt water saving technologies?: Findings of a market research study from north Gujarat, Paper presented at the annual partners' meet of the IWMI-Tata Water Policy Program, Anand, 27-29 January.

Verma, S., 2003, More crop per drop: Can micro-irrigation help alleviate groundwater depletion?, Paper presented at the 3rd World Water Forum, in "Groundwater Governance in Asia: The challenge of taming a colossal anarchy", Booklet published for the 3rd World Water Forum, International Water Management Institute, India.

Verma, S., Tsephal, S., and Jose, T., 2003, *Pepsee* systems: Grassroots innovation under groundwater stress, paper presented at the annual partners' meet of the IWMI-Tata Water Policy Program, Anand, 27-29 January.

Wolff, P., 1987, On the development status of micro-irrigation, Report No. 19 of the Department of Irrigation, Drainage and Soil Conservation, Faculty of International Agriculture, University of Kassel, Witzenhausen, Germany.

World Bank, 1993, Gains that might be made from water conservation in the Middle East, Washington DC., USA.

IWMI-Tata Water Policy Program

The IWMI-Tata Water Policy Program was launched in 2000 with the support of Sir Ratan Tata Trust, Mumbai. The program presents new perspectives and practical solutions derived from the wealth of research done in India on water resource management. Its objective is to help policy makers at the central, state and local levels address their water challenges – in areas such as sustainable groundwater management, water scarcity, and rural poverty – by translating research findings into practical policy recommendations.

Through this program, IWMI collaborates with a range of partners across India to identify, analyse, and document relevant water-management approaches and current practices.

The policy program's website promotes the exchange of knowledge on water- resources management within the research community and between researchers and policy makers in India.

IWMI-TATA WATER POLICY PROGRAM
Elecon Complex, Anand-Sojitra Road
Vallabh Vidyanagar, 388120, Gujarat, India
Telephone: 91-2692-229311-12-13
Fax: 91-2692-229311
E-mail: iwmi-tata@cgiar.org
Website: http://www.iwmi.org/iwmi-tata

HEADQUARTERS
127, Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address: P O Box 2075, Colombo, Sri Lanka
Telephone: +94 – 11- 2787404, 2784080 Fax: +94 – 11- 2786854
E-Mail: iwmi@cgiar.org

REGIONAL OFFICE FOR ASIA
(Bangladesh, China, Nepal and Sri Lanka)
127 Sunil Mawatha, Pelawatte, Battaramulla, Sri Lanka
Mailing Address: P O Box 2075, Colombo, Sri Lanka
Telephone: +94 1 867404, 869080, 869081, 872178, 872181
Fax: +94 1 866854; E-Mail: iwmi@cgiar.org

CHINA
Centre for Chinese Agricultural Policy, Chinese Academy of Sciences,
Building 917, Datun Road, Anwai, Beijing 100 101, China
Telephone: +86 10 64889440, 64856535, 64856837
Fax: +86 10 648556533; E-Mail: j.wang@cgiar.org

NEPAL
GPO 8975 EPC 416, Kathmandu, Nepal
Telephone: +977 – 1 – 5542306, 5535382 (Ext 486)
Mobile Tel: 981022573; Fax: +977 – 1 -5536219
E-Mail: d.pant@cgiar.org

REGIONAL OFFICE FOR AFRICA
141, Cresswell Street, 0184 Silverton, Pretoria, South Africa
Mailing Address: Private Bag x813, Silverton 0127, South Africa
Telephone: +27 12 8424132, 4125, 4128, 4131, 4136-9
Fax: +27 12 8040753; E-Mail: d.merrey@cgiar.org

KENYA
c/o ICRAF, United Nations Avenue, PO Box 30677, Nairobi, Kenya
Telephone: +254 2524751, 524000; Fax: +254 2524001
E-Mail: c.mutero@cgiar.org

SENEGAL
c/o WARDA/ADRAO, BP 96 St. Louis, Senegal
Telephone: + 221 9626493, 9626441; Fax: +221 9626491
E-Mail: p.fraval@cgiar.org

GHANA
c/o KNUST, Kumasi, Ghana
Telephone/Fax: +233 51 60206
E-Mail: iwmi-ghana@cgiar.org

REGIONAL OFFICE FOR SOUTH ASIA
IWMI South Asia Regional Office, ICRISAT, Patancheru,
Andhra Pradesh 502 324, India
Telephone: +91- 40 - 23296161; Fax: +91- 40- 23241239
E-Mail: iwmi-southasia@cgiar.org

REGIONAL OFFICE FOR PAKISTAN, CENTRAL ASIA AND MIDDLE EAST
12KM, Multan Road, Chowk Thokar,
NiazBaig, Lahore 53700, Pakistan
Telephone: +92 42 5410050-53
Fax: +92 42 5410054; E-Mail: a.qureshi@cgiar.org

UZBEKISTAN
Apartment No. 103, Home No. 6, Murtazaeva Street,
Tashkent 700000, Uzbekistan
Telephone: +998 71 1370445; Fax: +998 71 1370317
E-Mail: v.hornikova@cgiar.org

REGIONAL OFFICE FOR SOUTH-EAST ASIA
(Cambodia, Indonesia, Laos, Malaysia, Myanmar, Philippines,
Thailand, Vietnam)
PO Box 1025, Kasetsart University, Jatujak,
Bangkok 10903, Thailand
Telephone: +66 2561 4433; Fax: +66 2561 1230
E-Mail: d.j.bandaragoda@cgiar.org