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Economic Viability of Drip Irrigation: An Empirical Analysis from Maharashtra

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I

INTRODUCTION

Irrigation is essential for increasing the use of yield increasing inputs and enhancing cropping intensity and crop productivity (Dhawan, 1988; Vaidyanathan *et al.*, 1994; Narayanamoorthy, 1996 a). While the water need for irrigation is bound to grow with agricultural expansion and intensification imperatives, resource side constraints on the one hand and growing water demand from non-irrigation sectors on the other hand are likely to limit the water availability for irrigation.[1] In such scarce condition, efficient use of available water will be an important means to expand irrigation benefits (Government of India, 1995; Dhawan, 1995; Saleth, 1996). It is a known fact that the efficiency in the use of water is extremely low in the flood method of irrigation (FMI) because of evaporation and losses in conveyance and distribution (Sivanappan, 1994; Chaudhary, 1995).[2] Different measures (e.g., Command Area Development Programme and Water Users Organisation) have been introduced to improve water use efficiency under FMI. Unfortunately, these measures could not make any appreciable change in the existing pattern of water use.

Another method introduced in India recently to enhance water use efficiency in irrigation is the drip method of irrigation (DMI). Notably, the on-farm irrigation efficiency of properly designed and managed drip irrigation systems is about 90 per cent whereas it is about 70 per cent for sprinklers but just about 45 per cent for surface irrigation methods including FMI (Sivanappan, 1994; INCID, 1994). Obviously, the DMI is most useful for wide-spaced crops, especially water scarce areas. In this method, since water is supplied straight to crop-root zone through a network of pipes and drip emitters, water losses in conveyance and distribution are far lower than those under FMI (Shrestha and Gopalakrishnan, 1993).

Experimental results from research stations located in various parts of India do indicate that DMI increases crop yield and that too with reduced cultivation cost and water consumption (see Table 1).

Realising such benefits, the Government of India has introduced many promotional schemes including subsidy for drip adopters to increase the area under drip irrigation. For encouraging the use of sprinklers, drip systems and other water saving devices, the Government of India had released Rs. 11.96 crores between 1982-83 and 1991-92 to the State

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Governments under the Centrally sponsored scheme. But the growth of area under drip irrigation is insignificant barring a few states in India. For instance, at the end of 1992, India's total drip irrigated area was 70,589 hectares (ha) which is just 0.11 per cent of gross irrigated area (GIA) and 0.29 per cent of the net groundwater irrigated area (NGWIA). Though DMI increases the crop productivity and saves water (Magar *et al.*, 1988; Kulkarni, 1987), the huge initial investment needed for installing drip systems remains the main deterrent for the widespread adoption of DMI.[3] To what extent this discouragement effect is real and to what extent such effect can be counterbalanced by government subsidy are important policy issues requiring empirical answers. Since past studies (e.g., INCID, 1994; Sivanappan, 1994) on the subject have either conducted benefit-cost analysis without a proper methodology or relied on the experience of one or few farmers adopting DMI, there is a need for a study to empirically evaluate the economic viability of the new irrigation technique within a relatively more systematic methodological framework.

TABLE 1. YIELD GAINS AND WATER SAVING IN DRIP IRRIGATION OVER CONVENTIONAL IRRIGATION METHODS

(per cent)

Crop (1)	Yield gains (2)	Water saving (3)
Banana	52	45
Grapes	23	48
Mosambi	50	61
Pomegranate	98	45
Sugarcane	33	65
Tomato	50	39
Watermelon	88	36
Cotton	27	53
Lady's finger	16	40
Brinjal	14	53
Bitter gourd	39	53
Ridge gourd	17	59
Cabbage	2	60
Papaya	75	68
Radish	2	77
Beet root	7	79
Chillies	44	62
Sweet potato	39	60

Source: INCID (1994).

It is in this context that the present study aiming to empirically evaluate the economic viability of DMI assumes importance and relevance. Utilising field level data collected from 100 farmers - both adopters and non-adopters of DMI - spread in Jalgaon and Nashik districts of Maharashtra and a properly designed benefit-cost framework, this study attempts to empirically evaluate the economic viability of DMI in the case of two crops, i.e., banana and grapes, for which DMI is the most feasible irrigation technique. Specifically, this study addresses (i) the relative productivity gains, cost saving and water use efficiency possible with the new irrigation technology, (ii) the way the economic viability of investment on DMI is influenced by factors like fixed costs (i.e., the lumpiness of investment), (iii) government subsidies, and farmers' time preference (i.e., the differential discount rates).

II

EMPIRICAL CONTEXT

Maharashtra, a state with nearly a half of the total drip irrigated area in the country as of 1992, provides the empirical context for this study.[4] Both the Central and State schemes of subsidies on drip irrigation sets are currently in operation to promote DMI in Maharashtra. State schemes are operating since 1986-87 while Central schemes have started functioning only from 1990-91. Under these schemes, between 1986-87 and 1994-95, the Government of Maharashtra has distributed about Rs. 83.72 crores as subsidy to about 90,668 farmers using DMI. Thanks to this initiative, the area under DMI has increased from 236 ha in 1986-87 to about 60,120 ha in 1994-95, signifying an increase of about 254 times. Currently, about 20 crops are being cultivated using DMI.[5] Among different crops being cultivated with DMI, four crops, i.e., banana (11.67 per cent), grapes (27.28 per cent), orange (11.54 per cent) and sugarcane (16.69 per cent), together account for about 67 per cent of the total area in Maharashtra by the end of 1994-95.

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) ever 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 - were selected. Based on the crop and blockwise 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 were 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 were 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 were selected from each district. While the adopters were selected using random sampling procedure, non-adopters were selected rather purposively. Thus it is this sample of 100 farmers for whom the relevant data on the economics of DMI were collected during the year 1993-94 that forms the basis for the field level evaluation of DMI.

III

METHODOLOGY

Since it is essentially an impact evaluation study, the basic approach used for assessing the relative economic impact of DMI in crop cultivation involves a comparison between adopters and non-adopters (who use FMI) in the context of the same crop. To evaluate the economic viability of drip investment, in the context of both banana and grapes, we have computed both the Net Present Worth (NPW) and Benefit-Cost Ratio (BCR) by utilising the discounted cash flow technique. Since the NPW is the difference between the sum of the present value of benefits and that of costs for a given life period of the drip set, it collates the total benefits with the total costs covering items like capital and depreciation costs of the drip set. In terms of the NPW criterion, the investment on a drip set can be treated as economically viable if the present value of benefits is greater than the present value of costs.

The BCR is also related to NPW as it is obtained just by dividing the present worth of the benefit stream with that of the cost stream. Generally, if the BCR is more than one, then, the investment of that project can be considered as economically viable. A BCR greater than one obviously implies that the NPW of the benefit stream is higher than that of the cost stream. The NPW and BCR can be defined as follows:

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

$$\text{BCR} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \qquad \ldots.(2)$$

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

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

(i) The life period of a drip set is considered as five years for banana but ten years for grapes (see INCID, 1994).

(ii) The income stream from the drip set is uniform and constant over its entire life for both the crops. However, this assumption is later relaxed by considering alternative scenarios, wherein cash outflows are allowed to increase by 2 per cent and 5 per cent per annum over the corresponding cash inflows.

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

(iv) And, finally the crop cultivation technology is assumed constant for both banana and grapes.

IV

RESULTS AND DISCUSSION

As a backdrop to our benefit-cost analysis of DMI, we briefly discuss below the productivity and cultivation cost patterns under drip and non-drip irrigated conditions. Table 2 provides evidence for the differential pattern of productivity and cultivation cost among the adopters and non-adopters of DMI. It is clear that cultivation cost is comparatively lower among the adopters of DMI for both the regions and crops. 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.[6] 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. Likewise, since it supplies water only at the root zone of the crops, it provides the least scope for weed growth in non-crop space.

TABLE 2. CULTIVATION COST AND PRODUCTIVITY AMONG DRIP ADOPTERS AND NON-ADOPTERS, MAHARASHTRA, 1993-94

Particulars	Jalgaon (banana)		Nashik (grapes)	
	Adopters	Non-adopters	Adopters	Non-adopters
(1)	(2)	(3)	(4)	(5)
Land size (ha)	2.11	2.49	2.04	2.25
Net cultivated area (ha)	2.05	2.49	2.03	2.25
Percentage of area under DMI to cultivated area	59.21	-	28.39	-
Land use intensity (per cent)	97.43	100.00	99.73	100.00
Cost of cultivation (Rs./ha)	51,436.66	52,738.56	1,34,506.19	1,47,914.96
Productivity (qtl/ha)	679.54	526.35	243.25	204.29
Gross income (Rs./ha)	1,34,043.75	1,02,934.73	2,47,817.02	2,11,037.93
Profit (farm business income)†	82,607.09	50,196.17	1,13,310.83	63,122.97

Source: Calculated from field level data.
† Return over out-of-pocket expenses.

Regarding the productivity gains from DMI, 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, for grapes, the productivity difference is about 19 per cent between DMI and FMI. This higher crop productivity under DMI occurs mainly through higher water use efficiency and intensity. As DMI, unlike FMI, 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). It is clear that DMI saves water and reduces cultivation cost but enhances crop yield.

To complete the analysis of the relative economics of DMI and FMI, we did also calculate the relative profit levels of the adopters and non-adopters of DMI. In this calculation, while gross income was obtained by multiplying yield with the prevailing per quintal selling price, the total cost was calculated by considering only the variable costs but not the fixed cost components like interest rate and depreciation. As can be seen from Table 2, the average profit among drip adopters is significantly higher than that among non-drip adopters in the case of both the crops. For grapes, the profit level among drip adopters is Rs. 50,187/ha higher than that among non-adopters, whereas the same is about Rs. 32,400/ha for banana. While the profit differential is substantial for DMI, it cannot be taken as a conclusive indicator of the comparative advantages of the new irrigation technique as our profit calculation is based only on the variable cost but ignores fixed cost components like the interest rate and depreciation.

V

WATER USE EFFICIENCY

Water conservation and water use efficiency are among the two most important advantages of drip irrigation. Since water is supplied straight to the crop-root zone through a network of pipes and driplets, DMI leads to substantial reduction in water losses occurring from evaporation, conveyance and distribution. While quantifying such DMI-induced water loss reduction or water use efficiency, improvement requires an exact measurement of water delivery and actual water consumption by crops, in the context of a sample-based field study like the present one, it is inevitable to use the nearest practicable proxy like irrigation time in terms of the horse power (HP) hours to get a fair idea of the amount of water used. The HP hours of water are computed by multiplying the HP of the pumpset with the number of hours of irrigation. The amount of water use as measured in terms of HP hours of irrigation for drip and non-drip crops is presented in Table 3.

TABLE 3. WATER CONSUMPTION AND WATER USE EFFICIENCY IN DRIP AND NON-DRIP IRRIGATED CROPS, MAHARASHTRA, 1993-94

Particulars	Water consumption/ha†		Water used per quintal of yield	
	Banana	Grapes	Banana	Grapes
(1)	(2)	(3)	(4)	(5)
Drip crops (HP hours)	7,884.70	3,310.36	11.60	13.61
Non-drip crops (HP hours)	11,130.34	5,278.38	21.14	25.84
Water saved by DMI				
In percentage	29.15	37.28	45.13	47.33
In HP hours	3,245.64	1,968.02	9.54	12.23

Source: Computed from field level data.
† Our sample contains only the farmers using well irrigation by electric pumpsets.

It is clear from Table 3 that the amount of water applied for crops under drip irrigation is significantly lower than the same for crops which are cultivated under FMI. The extent of water saving as reflected through our proxy measure works out to about 29 per cent for banana and about 37 per cent for grapes. In terms of HP hours, however, water saving is substantially higher for water intensive crop like banana when compared with grapes. With an overall 30 per cent of saving in water effected through drip technology, one can estimate the additional area that can be irrigated even within the existing level of water availability. Our calculation shows that an additional area of 0.60 ha (1.48 acres) under grapes and 0.41 ha (1.01 acre) under banana can be irrigated by adopting DMI.

While the extent of additional area irrigated with a given amount of water is an important indicator for evaluating water use efficiency under DMI, a somewhat more precise method to judge the efficiency of water use in drip and non-drip irrigated conditions is to ascertain their relative water use per quintal of output. Note that the per quintal requirement of water is arrived by dividing the per hectare water consumption by the per hectare yield. The results (see Table 3) show that water use efficiency is substantially higher for the drip irrigated crops. 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 condition. Similarly, in the case of grapes, each quintal of output involves the use of just 13.6 HP hours of water under DMI as compared to the use of 25.84 HP hours under non-drip condition. Besides water saving, there is also substantial energy saving with DMI. According to our calculation done elsewhere, electricity saved due to the adoption of DMI is about 2,430 kWh/ha for banana and 1,470 kWh/ha for grapes (Narayanamoorthy, 1996 a,b,c). As in the case of water, electricity required to produce one quintal of output is also significantly less under DMI when compared with other traditional irrigation methods. It is rather obvious from our analysis that DMI extends irrigation benefits with equal productivity gains, that too, with reduced irrigation and energy costs. However, in order to have a complete analysis of the comparative economic advantages of DMI, it is necessary to bring into our analysis the fixed cost components that is often considered to operate against the expansion of DMI.

VI

CAPITAL AND PRODUCTION COST

DMI requires fixed capital for installing the drip system, the magnitude of which varies by crop. Wide-spaced crops require relatively low fixed capital but narrow spaced crops need higher fixed capital. Besides the crop type, the size of the fixed capital requirement is also sensitive to the quality of the materials used for the systems as well as the distance between the well and the field (NABARD, 1989). Let us now evaluate the empirical pattern of both the capital cost of the drip system and the production cost for our sample crops. The capital cost, subsidy, production cost (cost of cultivation) and gross value of production obtained for our sample are given in Table 4. Since both the crops are wide-spaced, there is only a marginal difference between the average capital cost of DMI for banana (Rs. 33,595/ha) and for grapes (Rs. 32,721/ha).

TABLE 4. CAPITAL COST, SUBSIDY AND PRODUCTION COST FOR DRIP IRRIGATED CROPS, MAHARASHTRA, 1993-94

(Rs./ha)

Particulars (1)	Banana (Jalgaon) (2)	Grapes (Nashik) (3)
Capital cost of drip set[a]		
i. Total cost of set	33,595.00	32,721.00
ii. Cost after deducting subsidy	22,236.00	20,101.00
Production cost (Cost of cultivation)[b]	51,437.00	1,34,506.19
Gross value of production	1,34,043.75	2,47,817.02
Subsidy	11,359.00	12,620.00

Notes: a. It does not cover pumpset cost.
b. Production cost includes also the operation and maintenance cost of drip set and pumpset.

As noted earlier, since DMI is capital intensive in nature, both the Central and State Governments try to provide nearly 50 per cent of the capital cost as subsidy to encourage the adopting farmers in Maharashtra.[7] The average capital subsidy comes to Rs. 11,359/ha for banana and Rs. 12,620/ha for grapes. As a proportion of the total capital cost of drip set, subsidy accounts for nearly 34 per cent for banana and 39 per cent for grapes. With this subsidy, the fixed capital cost of drip set comes down to about Rs. 22,236/ha for banana and about Rs. 20,101/ha for grapes.

VII

BENEFIT-COST ANALYSIS

Drip irrigation system is an investment yielding returns over time and the cash flows can change over time. Therefore, the analysis requires assumptions not only about the pattern but on the volatility of cash flows. In order to assess the potential role that subsidy plays in the adoption of DMI, computations are done separately by including subsidy and by excluding subsidy in the total fixed capital cost of drip set. Financial viability analysis under different rates of discount will indicate the stability of investment at various levels of the opportunity cost of investment. Although the BCR is sensitive to discount rate and the degree of such sensitivity depends on the pattern of cash flows, it is interesting to observe the sensitivity of the BCR when there is simultaneous change in both subsidy and discount factor. Table 5 presents the results of such sensitivity analysis computed under the assumption that there will not be any change in the cost of production and gross income during the entire life period of drip set. As expected, the NPW of the investment with subsidy is marginally higher than that under 'no subsidy' option. For instance, at 15 per cent discount rate, the NPW of drip investment for banana is about Rs. 2,47,753/ha without subsidy but Rs. 2,57,635/ha with subsidy. This means that the subsidy enables the farmers to get an additional benefit of Rs. 9,882/ha. It can also be noted that the difference between the NPW under the two scenarios is decreasing along with each increase in discount rate. The difference in NPW for the two scenarios which is Rs. 10,325 for banana and Rs. 11,471 for grapes at 10 per cent discount rate declines to Rs. 9,882 and Rs. 10,979 for banana and grapes respectively at 15 per cent discount rate. This differential behaviour of NPW across discount rates for the two crops is attributable to the observed differences in cash flows and cultivation practices and the assumed difference in drip set life span for the two crops. As seen from Table 5, the BCR without subsidy for banana that is about 2.253 at 10 per cent discount rate slides down to 2.228 at 15 per cent discount rate. For grapes, in contrast, the BCR declines only marginally as the rate of discount increases. Although the same pattern of decline in BCR is observed across discount rates even under the alternative scenario of cash flows with subsidy, the BCR is higher with subsidy than otherwise. This suggests the positive role that subsidy plays in improving the economic viability of DMI for our sample crops irrespective of the time preference of the farmers.

TABLE 5. SENSITIVITY ANALYSIS OF NPW AND BCR COMPUTED BY ASSUMING NO CHANGE IN THE COST OF PRODUCTION AND GROSS INCOME DURING THE LIFE PERIOD OF THE DRIP SET

Items	Scenario-I		Scenario-II	
(1)	Banana (2)	Grapes (3)	Banana (4)	Grapes (5)
Net present worth (Rs./ha)				
At 10 per cent discount rate	2,82,542	6,66,440	2,92,867	6,77,911
At 12 per cent discount rate	2,67,797	6,10,987	2,77,941	6,22,257
At 15 per cent discount rate	2,47,753	5,40,241	2,57,635	5,51,220
Benefit-cost ratio				
At 10 per cent discount rate	2.253	1.778	2.361	1.802
At 12 per cent discount rate	2.243	1.774	2.353	1.799
At 15 per cent discount rate	2.228	1.767	2.343	1.795

Notes: Scenario-I is computed without considering capital subsidy for drip set.
Scenario-II is computed after deducting capital subsidy for drip set.

Another policywise important economic issue in the context of DMI adoption is the number of years needed to recover fully the capital costs involved in drip installation. Our computation of NPW for both banana and grapes clearly shows that the farmers can recover the entire capital cost of the drip set from their net profit in the very first year itself. This finding contradicts the general belief that the capital cost recovery for drip investment takes more time. More importantly, when the farmers can recover the capital costs within a year, the role of discount rate as a device to capture the time preference of the farmers seems to be of considerably lesser importance than one might think. However, in order to have a more definite answer to the economic and social viability of DMI, we need a social rather than the private cost-benefit evaluation being attempted here. A comprehensive evaluation can be done by incorporating both the social benefits in the form of water saving, additional irrigation benefits, lower soil degradation and retention of soil fertility as well as the social costs in terms of the negative food and fodder implications of crop pattern shift and labour displacement.

While the sensitiveness of both the BCR and NPW to discount rate and subsidy has already been shown, let us now show how these project criteria and hence, the viability analysis are influenced by differential temporal behaviour of cost (cash outflow) and income (cash inflow) streams. Of particular importance from the viewpoint of the economic viability of DMI is the issue of what happens when cost stream in terms of cash outflows increases at a rate higher than the income stream. If the cash outflows increase at a rate sufficient to exceed the rate of increase in the income stream, the investment may prove to be non-viable after a while. This means that the viability of DMI depends crucially on factors like farm cost escalation and inflation. To address the influence of input cost escalation on the economic viability of drip investment, we perform viability computations by assuming an annual cost escalation of 2 and 5 per cent. The results of the sensitivity analysis for the two crops are presented in Tables 6(A) and 6(B) respectively. The lowest BCR observed for grapes is 1.47 with discount rate at 10 per cent and cost escalation at 5 per cent. In the case of grapes, although the BCR declines with the rate of discount, the change is not perceptible. Overall, the sensitivity analysis under various contexts indicates that drip investment remains economically viable even without subsidy. Even though subsidy is not needed to enhance the economic viability of the drip system, it is still needed to enhance the incentive for the widespread adoption of DMI particularly among smaller farmers. From the policy point of view, this result suggests that subsidy can be phased out eventually once the new irrigation technology covered an area adequate enough to expand subsequently through the demonstration effect.

TABLE 6 (A). SENSITIVITY ANALYSIS OF NPW AND BCR UNDER DIFFERENT SCENARIOS FOR BANANA

Items (1)	Scenario A-I[1] (2)	Scenario A-II[2] (3)	Scenario B-I[3] (4)	Scenario B-II[4] (5)
Net present worth (Rs./ha)				
At 10 per cent discount rate	2,75,348	2,64,037	2,85,673	2,74,362
At 12 per cent discount rate	2,61,090	2,50,549	2,71,234	2,60,692
At 15 per cent discount rate	2,41,700	2,32,192	2,51,582	2,42,075
Benefit-cost ratio				
At 10 per cent discount rate	2.183	2.082	2.285	2.174
At 12 per cent discount rate	2.175	2.077	2.279	2.171
At 15 per cent discount rate	2.163	2.069	2.271	2.167

Notes: 1. Scenario A-I is computed by assuming 2 per cent increase per annum in the cost of production and without considering subsidy amount of the capital cost of drip set.
2. Scenario A-II is computed by assuming 5 per cent increase per annum in the cost of production and without considering subsidy amount of the capital cost of drip set.
3. Scenario B-I is computed by assuming 2 per cent increase per annum in the cost of production and after deducting subsidy amount from the capital cost of drip set.
4. Scenario B-II is computed by assuming 5 per cent increase per annum in the cost of production and after deducting subsidy amount in the capital cost of drip set.

TABLE 6(B). SENSITIVITY ANALYSIS OF NPW AND BCR UNDER DIFFERENT SCENARIOS FOR GRAPES

Items (1)	Scenario A-I[1] (2)	Scenario A-II[2] (3)	Scenario B-I[3] (4)	Scenario B-II[4] (5)
Net present worth (Rs./ha)				
At 10 per cent discount rate	6,01,768	4,92,197	6,13,240	5,03,668
At 12 per cent discount rate	5,53,836	4,57,237	5,65,106	4,68,507
At 15 per cent discount rate	4,92,405	4,11,836	5,03,384	4,22,815
Benefit-cost ratio				
At 10 per cent discount rate	1.654	1.477	1.674	1.494
At 12 per cent discount rate	1.654	1.484	1.676	1.502
At 15 per cent discount rate	1.655	1.495	1.679	1.515

Notes: Same as in Table 6 (A).

VIII

CONCLUSION

The field level results reported in this paper do confirm that DMI not only contributes to water conservation and additional irrigation benefits but also reduces cultivation cost and increases the crop productivity as compared to conventional irrigation methods. The NPW calculation shows that in the case of banana and grapes cultivation, the farmers can recover the fixed investment cost on drip irrigation system at the end of the first year itself even in the absence of government subsidy. The economic viability of the drip system holds good even for farmers with just one hectare of land. Since the benefit-cost ratio computed with different discount rates stands between 2.07 and 2.36 for banana and between 1.48 and 1.80

for grapes, investment in drip irrigation system is economically viable for these crops. Even though subsidy is not a pre-requisite to enhance the economic viability of drip investment, it is still needed to enhance the widespread adoption of DMI particularly by smaller farmers. From the view point of public policy, this result indicates that subsidy can be phased out gradually when the new irrigation technology covers an area adequate enough to expand subsequently on its own through the demonstration effect.

Water use efficiency and conservation are the two main benefits of drip irrigation technology. Our results do provide evidence for significant improvements in water and energy use efficiency under drip irrigation. With an enhanced efficiency in water use, additional area can be irrigated with substantial output even with the existing levels of water availability. Our calculation shows that for every hectare of land brought under drip irrigation, an additional area of 0.60 ha of grapes and 0.41 ha of banana can be brought under irrigation.

Though DMI has many economic and resource related advantages over FMI, its growth in terms of area is not appreciable barring a few states. The results from our field-based study reveal that the slow growth of DMI is not due to economic reasons but mainly due to the lack of awareness among the farmers about the real economic and resource-related advantages of the new irrigation technology. This means that apart from the provision of capital subsidy, there is also an urgent need for an awareness campaign through an effective extension network including field level demonstration in targeted areas. Besides, every state government needs to formulate a target-oriented programme including incentive packages as being followed in Maharashtra to increase the area under DMI. While subsidy has an important role in the immediate stage, the long-term strategy involves the creation of an effective extension network and service centres for drip irrigation technology.

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NOTES

1. Irrigation water demand, accounting for a three-fourth share in total water demand, is projected to increase from 470 cubic kilometres (ckm) in 1985 to 740 ckm by 2025 A.D. Such a faster growth of water demand in the face of emerging supply constraints is likely to result in a supply gap for irrigation water in the near future. In the meantime, the non-irrigation water demand is projected to grow from 70 ckm in 1985 to 280 ckm by 2025 A.D., indicating a four-fold increase. This will additionally put pressure on water resources (see Vaidyanathan, 1994; Saleth, 1996).

2. Estimates show that the total water loss in conveyance is as high as about 70 per cent - about 15 per cent in canals, 7 per cent in distributaries, 22 per cent in watercourses and 27 per cent in farm fields (Chaudhary, 1995).

3. The capital cost of drip system varies depending upon the nature of crops, terrain conditions and the distance of water source. As per the estimates of the National Committee on the Use of Plastics in Agriculture (NCPA), the capital cost of a drip set varies from Rs. 30,000 to Rs. 33,000/ha for crops like sugarcane and vegetables and from Rs. 11,000 to Rs. 19,000/ha for wide-spaced crops like coconut, orange, mango and pomegranate (INCID, 1994).

4. In 1992, India's total drip irrigated area was 70,589 ha, of which Maharashtra State alone accounted for 32,924 ha, constituting about 46 per cent of the country's total area under DMI.

5. For more details in this regard, see Narayanamoorthy (1996 a).

6. As the main focus of the paper is on the overall benefit-cost pattern of drip investment, the operationwise cost saving possible from DMI has not been elaborated here but it can be seen in Narayanamoorthy (1996 a).

7. In the new guidelines effective from May 14, 1992, the subsidy that remains invariant across land holding size is limited to either 50 per cent of the actual capital cost or Rs. 15,000/ha, whichever is lower. Unlike other schemes, here there is no direct link between subsidy and bank loan. Subsidy is sanctioned on the basis of the recommendation and verification by the agricultural officials.

REFERENCES

Chaudhary, T.N. (1995), "INDIA", in Asian Productivity Organisation (1995), *Agricultural Water Management Technology in Asia and the Pacific*, Tokyo, pp. 162-164.

Dhawan, B.D. (1988), "Role of Irrigation in Raising Intensity of Cropping", *Journal of Indian School of Political Economy,* Vol. 3, No. 4, October-December, pp. 632-671.

Dhawan, B.D. (1995), "Magnitude of Groundwater Exploitation", *Economic and Political Weekly,* Vol. 30, No. 14, April 8, pp. 769-775.

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

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

Kulkarni, S.Y. (1987), "Sprinkler and Drip Irrigation System", *Sinchan*, Vol. 6, No. 3, October, pp. 56-61.

Magar, S.S.; N.N. Firke and J.R. Kadam (1988), "Importance of Drip Irrigation", *Sinchan,* Vol.7, No. 2, July, pp. 61-62.

National Bank for Agriculture and Rural Development (NABARD) (1989), *Sprinkler Irrigation in Semi-Arid Areas of Rajasthan: An Ex-Post Evaluation Study,* Evaluation Study Series No. 36, Bombay.

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

Narayanamoorthy, A. (1996 b), "Impact of Drip Irrigation on Consumption of Water and Electricity", *The Asian Economic Review,* Vol. 38, No. 3, December, pp. 350-364.

Narayanamoorthy, A. (1996 c), "Adoption of Recommended Use of Fertilisers and Its Impact on Paddy Yield: An Analysis of Determinants in Groundwater Irrigated Region", *Artha Vijnana,* Vol. 38, No. 4, December, pp. 387-406.

Saleth, R. Maria (1996), *Water Institutions in India: Economics, Law, and Policy,* Commonwealth Publishers, New Delhi.

Shrestha, B. Rajendra. and Chennat Gopalakrishnan (1993), "Adoption and Diffusion of Drip Irrigation Technology: An Econometric Analysis", *Economic Development and Cultural Change,* Vol. 41, No. 2, January, pp. 407-418.

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

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

Vaidyanathan, A.; Asha Krishnakumar, A. Rajagopal and D. Varatharajan (1994), "Impact of Irrigation on Productivity of Land", *Journal of Indian School of Political Economy,* Vol. 6, No. 4, October-December, pp. 601-645.