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लेखक

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प्राध्यपक और निदेशक

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PREFACE

Though the area under irrigation has increased significantly since independence, the share of irrigated area to gross cropped area in Indian agriculture is only about 40 percent as of today. One of the main reasons for the limited expansion of irrigation is the predominant use of flood method of irrigation. The efficiency of water use under flood method of irrigation is extremely low mainly due to huge losses through the evaporation and distribution. Considering the fast decline of available water potential and growing needs for irrigation water, various measures have been introduced to increase the efficiency of water use under flood method of irrigation. However, these measures could not bring any substantial improvement in the existing water use efficiency. Drip method of irrigation introduced somewhat recently in Indian agriculture proved to be an effective method in increasing the efficiency of water use. Drip method of irrigation supplies water directly at the root zone of the crops through a network of pipes and therefore, it substantially reduces the evaporation and distribution losses of water. Apart from water saving, drip method of irrigation also significantly increases productivity of crops and that too with reduced cost of cultivation. Although drip method of irrigation has been commercially practiced since mid-eighties in India, not many comprehensive studies are available focusing on the impact of it on various parameters of crops. In this study, using both secondary and field level data, an attempt is made to investigate the coverage of drip method of irrigation and its impact on cost of cultivation, production and productivity of different crops, water saving and water use efficiency as well as economic viability of drip investment in different crops. An attempt is also made to estimate the total potential area for drip method of irrigation and water saving for the country as a whole.

The results of the study show that water saving and water use efficiency of different crops cultivated under drip method of irrigation is significantly higher when compared with those under flood method of irrigation. Productivity as well as profit of different crops is also found to be higher with the crops cultivated under drip method of irrigation. This new irrigation technology also helps to save considerable amount of electrical energy used for lifting water from wells. Benefit-cost ratios with different discount rates indicate that drip investment in sugarcane, banana and grapes cultivation remains economically viable even without subsidy. The findings as well as the

policy recommendations of the study are expected to be useful for promoting the drip method of irrigation in India.

This paper is the outcome my research on drip irrigation that I have been undertaking since 1995, when I first carried out a field data based study on *Evaluation of Drip Irrigation System in Maharashtra* for the Ministry of Agriculture, Government of India, New Delhi. At the outset, I would like thank the Department of Economic Analysis and Research, National Bank for Agriculture and Rural Development (NABARD), Mumbai for extending an invitation to write this paper. Over the last ten years, I have had opportunities to discuss with various scholars about the issues pertaining to drip irrigation at different time points, which helped to refine my knowledge on this subject. Particularly, I would like to express my gratitude to the following scholars/administrators: Prof. R.S. Deshpande (Head, Agricultural Development and Rural Transformation Unit, Institute for Social and Economic Change, Bangalore), Prof. V.S. Chitre (former Director, Gokhale Institute of Politics and Economics, Pune and currently Director, Indian School of Political Economy, Pune), Prof. R. Maria Saleth (Senior Institutional Economist, International Water Management Institute, Colombo, Sri Lanka), Prof. B.D. Dhawan (former Professor, Institute of Economic Growth, Delhi), Dr. M.A. Chitale (former Secretary, Ministry of Water Resources, Government of India, New Delhi and former Secretary General, International Commission on Irrigation and Drainage, New Delhi), Shri V.M. Ranade (former Secretary of Irrigation, Government of Maharashtra, Mumbai), Prof. C. Ramasamy (Vice-Chancellor, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Prof. K. Palanisami (Director, Water Technology Centre, Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu), Prof. Tushaar Shah, (Theme Leader, Sustainable Groundwater Management, International Water Management Institute, V.V. Nagar, Gujarat, India), Dr. N.A. Mujumdar (Editor, Indian Journal of Agricultural Economics, Mumbai) and Shri Ajit B. Jain (Joint Managing Director, Jain Irrigation Systems Limited, Jalgaon, Maharashtra).

I have also benefited from many officials from the office of the Commissionerate of Agriculture, Government of Maharashtra, Pune, while carrying out the studies on drip method of irrigation over the years in Maharashtra. I express my sincere thanks to all those officials who have helped in my research endeavour.

Thanks are also due to Shri Bipin K Deokar, Shri Mukund N Deshpande and Shri Mahendra H Bhalerao for processing and

analysing the data using computer and Shri S.S. Dete, Shri V.B. Lokare and Shri V.G. Kasbe for collecting data from the field at different time points. However, none of the individuals and institutions mentioned above are responsible for errors remaining in the study report.

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Abbreviations

AFC	–	Agricultural Finance Corporation
BCR	–	Benefit-Cost Ratio
CACP	–	Commission for Agricultural Costs and Prices
CBIP	–	Central Board of Irrigation and Power
CGWB	–	Central Groundwater Board
CMIE	–	Centre for Monitoring Indian Economy
CI	–	Cropping Intensity
CM	–	Centimeter
CWC	–	Central Water Commission
DMI	–	Drip Method of Irrigation
DSI	–	Deccan Sugar Institute
FMI	–	Flood Method of Irrigation
FAI	–	Fertiliser Association of India
GCA	–	Gross Cropped Area
GWA	–	Groundwater Area
GIA	–	Gross Irrigated Area
GOI	–	Government of India
GOM	–	Government of Maharashtra
HP	–	Horse Power
ICID	–	International Commission on Irrigation and Drainage
INCID	–	Indian National Committee on Irrigation and Drainage
IWMI	–	International Water Management Institute
JISL	–	Jain Irrigation Systems Limited
MI	–	Minor Irrigation
MMI	–	Major and Medium Irrigation
MOWR	–	Ministry of Water Resources
NABARD	–	National Bank for Agriculture and Rural Development
NAT	–	New Agricultural Technology

NCPA	–	National Committee on the Use of Plastics in Agriculture
NCPAH	–	National Committee on Plasticulture Applications in Horticulture
NHB	–	National Horticulture Board
NPW	–	Net Present Worth
NIA	–	Net Irrigated Area
PFDC	–	Precision Farming Developing Centre
PIM	–	Participatory Irrigation Management
TFMI	–	Task Force on Micro Irrigation
VSI	–	Vasantdada Sugar Institute
WEM	–	Water Extraction Machinery
WUE	–	Water Use Efficiency

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EXECUTIVE SUMMARY

1. Recognising the fast decline of irrigation water potential and growing demand for water from different sectors, a number of demand curtailing strategies have been introduced since the late seventies to increase the water use efficiency especially in the use of surface irrigation water. However, the net impact of these strategies in increasing the water use efficiency is not very impressive as of today. One of the technical means introduced recently in Indian agriculture to improve the water use efficiency is drip method of irrigation (DMI). Unlike flood method of irrigation (FMI), under drip method, water is directly supplied to the root zone of the crops through a network of pipes using drippers/emitters. The direct supply of water through the pipe network reduces the substantial amount of water losses that take place usually under surface method of irrigation. As a result, the water use efficiency increases upto 100 percent in a properly designed and managed drip irrigation system. Drip method of irrigation also helps to reduce the over-exploitation of groundwater that partly occurs because of inefficient use of water under surface method of irrigation. This new method of irrigation also increases the productivity of crops and reduces the cost of cultivation especially in labour-intensive operations. Environmental problems associated with the surface method of irrigation namely water logging and salinity are also completely absent under drip method of irrigation.

2. Though drip method of irrigation can be efficiently used for various crops in water scarce countries like India, the coverage of area under DMI is very limited as of today. While studies have been carried out to find out the reasons for the slow growth of DMI as well as its impact on various parameters, most of the studies available in the Indian context are either based on experimental data or individual farmer case studies. Since the farm level situation is totally different from that of the experimental station, one requires a detailed study using data from properly designed survey for making any firm conclusion about its water use efficiency. The other issue of drip irrigation is related to its economic viability, as farmers are often reluctant to adopt this technology fearing that the technology may not be economically viable. Keeping in view the limitations of the existing studies, in this study, an attempt is made to study the impact of drip method of irrigation on different parameters as well as its potential and prospects in India using both secondary (experimental) and field level data.

3. Due to various promotional schemes introduced by the Government of India and States like Maharashtra, the area under drip method of irrigation has increased from 1500 ha in 1985-86 to 70589 ha in 1991-92 and further to 4.50 lakh hectares at the end of March 2003. Though drip method of irrigation has been in operation over the last two decades, it is essentially considered as a scheme of government. As of 1997-98, area under DMI other than government schemes (without subsidy) accounted for only about 18 percent of India's total drip irrigated area.

4. Over the last ten years, significant growth has been achieved in area under drip method of irrigation in absolute term in many States. However, drip irrigated area constitutes a very meagre percentage in relation to gross irrigated area in all the States in India. During 2000-01, the share of drip-irrigated area to gross irrigated area was just 0.48 percent and about 1.09 percent in relation to total groundwater irrigated area of the country.

5. State-wise area under drip method of irrigation pertaining to three time points namely 1991-92, 1997-98 and 2000-01 shows a substantial improvement in the adoption of this new irrigation technology across the States. However, the development of drip method of irrigation is not uniform across different states. In all three time points, Maharashtra State alone accounted for nearly 50 percent of the India's total drip irrigated area followed by Karnataka, Tamil Nadu and Andhra Pradesh. There are many reasons for the rapid development of drip irrigation in Maharashtra. First, State government is very keen in promoting drip irrigation on a large scale by providing subsidy, technical and extension services to the farmers. Maharashtra government has been providing subsidy since 1986-87 onwards through State schemes. Second, area under irrigation from both surface and groundwater is quite low and hence, many farmers have adopted drip method of irrigation to avoid water scarcity largely in divisions like Nashik, Pune, etc. Third, owing to continuous depletion of groundwater, farmers were not able to cultivate wide spaced and more lucrative crops like grapes, banana, pomegranate, orange, mango, etc. using surface method of irrigation in many regions. As a result, farmers had to adopt drip irrigation as these crops are most suitable for drip method of irrigation. Importantly, the farmers who adopted drip irrigation initially for certain crops have realised the importance of drip irrigation in increasing the water saving and productivity of crops. This has further induced many farmers to adopt drip method in some of the regions in Maharashtra.

6. Water saving and improved water use efficiency are the two important advantages of drip method of irrigation. According to the experimental data from different research stations located in India, water saving due to drip method of irrigation varies from 12 to 84 percent over the conventional method of irrigation in vegetable crops. In fruit crops, water saving varies 45 to 81 percent. In sugarcane, which is a water-intensive crop, water saving is estimated to be over 65 percent due to drip method of irrigation.

7. The results of field level data pertaining to three crops namely sugarcane, banana and grapes are somewhat different from the experimental results. 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. However, 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.

8. Water consumption (in quantity) per hectare is much less under drip method of irrigation as compared to flood method of irrigation in all the three crops. 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.

9. Additional area can also be brought under irrigation from the saving of water realised through the adoption of drip method of irrigation. The additional irrigated area possible from the saving of water is estimated to be 0.80 (1.98 acres) in sugarcane, 0.60 ha (1.48 acres) in grapes and 0.41 ha (1.01 acres) in banana.

10. Water use efficiency (i.e., water consumed to produce one unit of crop output) is also significantly higher in drip-irrigated crops when compared to the same crops cultivated under non-drip irrigated condition. 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. In 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 of water under non-drip irrigated condition.

11. Saving in electrical energy use (used for lifting water from wells) is one of the important advantages of drip method of irrigation. While the researchers have not estimated the saving of electricity using experimental data, we have estimated electricity consumption using the field level data for both the drip and the non-drip irrigated crops. Consumption of electricity per hectare is quite low for drip-irrigated crops when compared to the same crops cultivated with flood method of irrigation. Farmers cultivating sugarcane under drip method of irrigation could save about 1059 kwh of electricity per hectare as compared to those farmers cultivating the same crop under flood method of irrigation. Similarly, while the farmers cultivating grapes could save about 1476 kwh/ha due to DMI, the same is estimated to be about 2434 kwh/ha in banana over the farmers who have cultivated these crops under FMI.

12. Efficiency in electricity use, which is measured in terms of requirement of electricity to produce one unit of output, is also significantly less under drip method of irrigation in all three crops considered for the analysis. 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.

13. Electricity saving from drip method of irrigation also helps the farmers to reduce electricity bill to be paid. Our estimate based on the current average cost of electricity supply in Maharashtra (Rs. 3.26/kwh) shows that, on an average, about Rs. 3454/ha can be saved on electricity bill alone by cultivating sugarcane crop under drip method of irrigation. Similarly, farmers cultivating grapes and banana under DMI can also save Rs. 4811 and Rs. 7934/ha respectively on account of electricity.

14. Besides water and electricity saving, reduction in cost of cultivation and improvement in productivity are the two other advantages of drip method of irrigation. Since the cost of cultivation details for different crops cultivated under DMI are not available from experimental data, the study utilised only the field level data pertaining to three above-mentioned crops. Cost of cultivation (cost A_2) per hectare of the adopters is found to be relatively less when compared to the non-adopters of drip irrigation in all three crops. The cost saving in sugarcane crop due to DMI is nearly 14 percent

(in absolute term Rs. 6550/ha). Farmers who cultivated grapes and banana under DMI have incurred relatively lower cost of cultivation. In case of banana, drip irrigation reduces the total cost of cultivation by about Rs. 1300/ha (2.47 percent) as compared to the farmers who cultivated the same crop under flood method of irrigation. In case of grapes, cost saving due to DMI is found to be Rs. 13408/ha (about 9 percent). Though the reduction in cost of cultivation in terms of percentage is relatively less, cost saving is found to be very high in operations like irrigation, weeding and interculture, furrows and bunding and fertilisers.

15. Productivity of crops cultivated under drip method of irrigation is significantly higher than the same crops cultivated under flood method of irrigation. Experimental data show that productivity increase due to DMI is over 40 percent in vegetable crops such as bottle gourd, potato, onion, tomato and chillies. Productivity increase due to DMI is noticed over 70 percent in many fruit crops. In sugarcane, the productivity gain is estimated to be over 33 percent. Similar kind of productivity gains is also noticed in different crops cultivated under experimental condition.

16. Similar to experimental results, considerable amount of productivity gain is also noted from the analysis of farm level data. The productivity difference in absolute term between the adopters and the non-adopters of drip method of irrigation comes to nearly 259 quintals per hectare for sugarcane, i. e., productivity of sugarcane cultivated under drip method of irrigation is higher by about 23 percent. In case of grapes, the productivity difference between DMI and FMI irrigated crops comes to about 19 percent (about 39 quintals) and the same comes to 29 percent (about 153 quintals) in case of banana crop. In spite of incurring higher cost on yield increasing inputs, productivity of crops cultivated under FMI is significantly lower than that of DMI. There are three main reasons for higher yield in drip-irrigated crops. First, because of less moisture stress, the growth of crop was good which ultimately helped to increase the productivity of crops. Second, unlike surface method of irrigation, drip does not encourage any growth of weed especially in the non-crop zone. Weeds consume considerable amount of yield increasing inputs and reduce the yield of crops in surface method of irrigation. Third, unlike surface method of irrigation, fertiliser losses occurring through evaporation and leaching through water are less under drip method of irrigation as it supplies water only for crop and not for the land.

17. Cost efficiency (i.e., cost incurred to produce one unit of output) is also found to be significantly higher for the drip adopters when compared to the non-drip adopters in all three crops. The non-drip adopters have incurred nearly three rupees over the adopters of drip method of irrigation to produce every quintal of sugarcane. In grapes, the non-adopters have incurred over Rs. 171 per quintal of output over the adopters. In banana, the non-adopters have incurred nearly Rs. 30 to produce one quintal of output over the counterpart. This higher cost efficiency is possible mainly because of significant increase in productivity of crops due to drip method of irrigation.

18. The undiscounted profit per hectare (gross income minus cost A_2) of the drip adopters is significantly higher than that of the non-drip adopters in all three crops analysed utilising field level data. Profit of the adopters in sugarcane is Rs. 27424/ha higher than that of the non-drip adopters. In grapes, the profit level of the drip adopters is Rs. 50187/ha higher than that of the non-adopters and for banana, the same is about Rs. 32400/ha. The study also noted that the huge profit from drip irrigation is not because of price effect, but only due to the yield effect in all three crops.

19. The capital cost required for installing drip investment for different crops has been increasing over the years due to increase in the cost of materials used for manufacturing drip system. The capital cost of drip system largely depends upon the type of crop (narrow or wide spaced crops), spacing followed for cultivating crops, proximity to water source (distance between the field and source of water) and the materials used for the system. Wide spaced crops generally require less capital when compared to the crops with narrow space, as the latter crops would require more laterals and drippers per hectare. Data available in INCID (1994) shows that the requirement of capital cost is much higher for banana (Rs. 33765/ha) as compared to the same required for mango (Rs. 11053/ha), which is a wide spaced crop.

20. Field level data pertaining to sugarcane, banana and grapes also shows variation in the requirement of capital cost needed for drip irrigation system. While the capital cost without subsidy comes to Rs. 52811/ha for sugarcane, the same comes to Rs. 32721/ha for grapes and Rs. 33595/ha for banana. The average capital subsidy comes to Rs. 19263/ha for sugarcane, Rs. 11359/ha for grapes and Rs. 12620/ha for banana. As a proportion of the total capital cost of drip set, subsidy amount accounts for about 35 to 37 percent, which is within a limit of provision made by the Government of Maharashtra.

21. As regards Benefit-Cost (B-C) ratio, the results available from INCID (1994) show that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account subsidy given to farmers. The B-C ratio estimated excluding water saving varies from 1.31 in sugarcane to 13.35 in grapes. The B-C ratio increases significantly further, when it is estimated after including water saving. Sivanappan (1995) also estimated B-C ratio for different crops cultivated under DMI using data pertaining to the year 1993. It also indicates that the investment in drip irrigation is economically viable, as B-C ratio estimated for different crop comes to more than one. While the B-C ratio for pomegranate is estimated to be 5.16, the same is estimated to be 1.83 for cotton, which is a less-water intensive as well as a narrow spaced crop. However, it was not clear whether the B-C ratio available from the studies of INCID and Sivanappan is estimated using discounted cash flow technique.

22. The economic viability of drip investment is also studied using discounted cash flow technique under with and without subsidy conditions, using field level data pertaining to three crops. Different discount rates considered for analysis are 10, 12 and 15 percent. The estimated results show that the Net Present Worth (NPW) of the investment with subsidy is marginally higher than that under 'no subsidy' option in all three crops. The year-wise calculation of NPW also shows that drip adopters can realise the whole capital cost of drip-set from the profit of the very first year itself.

23. Under different discount rates, the benefit-cost ratio (BCR) is computed to know whether the drip investment for three crops is economically viable or otherwise. The benefit-cost ratio is much higher than one under different discount rates even without subsidy. While the B-C ratio in sugarcane varies from 1.909 to 2.095 under without subsidy condition, the same varies from 2.098 to 2.289 under with subsidy condition. In case of banana, the B-C ratio varies from 2.228 to 2.253 under without subsidy condition and 2.343 to 2.361 under with subsidy condition. Similarly, in grapes, the B-C ratio without subsidy varies from 1.767 to 1.778 and from 1.795 to 1.802 with subsidy. The higher BCR under subsidy condition suggests the positive role that subsidy plays in improving the economic viability of drip method of irrigation.

24. India has enormous potential for drip method of irrigation. Our attempt made in this study to estimate the potential and prospects for drip method of irrigation shows that while "core potential"

(suitable crops that are cultivated under irrigated and non-irrigated conditions) comes to 51.42 mha, the “net potential” (suitable crops that are cultivated only under irrigated conditions) comes to 21.27 mha for the country as a whole. The requirement for capital to utilise the “core” and “net potential” areas is estimated to be about Rs. 183508 crore and Rs. 76434 crore respectively. That is, the requirement of capital per hectare comes to about Rs. 35688 for “net potential” and Rs. 35935 for “core potential”. By utilising the “net potential” area of DMI, an amount of about 11.271 million-hectare meter of water can be saved. The additional irrigated area possible from the saving of water is estimated to be 11.22 mha under FMI or about 24.12 mha under DMI.

Chapter 1

Introduction

1.1 An Overview

It has been corroborated by various studies carried out across different countries including India that irrigation plays a paramount role in increasing the use of yield increasing inputs and enhancing cropping intensity as well as productivity of crops (Dhawan, 1988; Vaidyanathan, et al., 1994). Apart from benefiting the farmers, irrigation development also helps to increase the employment opportunities and wage rate of the agricultural landless labourers, both of which are essential to reduce the poverty among the landless labour households (Saleth, 2004; Narayanamoorthy, 2001a; Bhattarai and Narayanamoorthy, 2003; Narayanamoorthy and Deshpande, 2003). However, water is becoming increasingly scarce worldwide due to various reasons (Rosegrant, et al., 2002). With the fast decline of irrigation water potential and continued expansion of population and economic activity in most of the countries located in arid and semi-arid regions, the problems of water scarcity is expected to be aggravated further (see, Biswas, 1993 and 2001; Rosegrant, 1997; Rosegrant, et al., 2002). Macro-level estimate carried out by the International Water Management Institute (IWMI), Colombo, indicates that one-third of the world population would face absolute water scarcity by the year 2025 (Seckler, et al., 1998; Seckler, et al., 1999). As per this estimate, the worst affected areas would be the semi-arid regions of Asia, the Middle-East and Sub-Saharan Africa, all of which are already having heavy concentration of population living below poverty line.

Despite having the largest irrigated area in the world, India too has started facing sever water scarcity in different regions. Owing to various reasons the demand for water for different purposes has been continuously increasing in India, but the potential water available for future use has been declining at a faster rate (Saleth, 1996). The agricultural sector (irrigation), which currently consumes over 80 percent of the available water in India, continues to be the major water-consuming sector due to the intensification of agriculture (see, Saleth, 1996; MOWR, 1999, Iyer, 2003). Though India has the largest irrigated area in the world, the coverage of irrigation is only about 38 percent of the gross cropped area as of today. One of the main reasons for the low coverage of irrigation is poor water use efficiency under the flood (conventional) method of irrigation, which is predominantly practised in Indian agriculture. Available estimates indicate that water use efficiency under flood method of irrigation is only about 35 to 40 percent (Rosegrant, 1997). Considering the water availability for future use and the increasing demand for water from different sectors, a number of demand and supply management strategies have been introduced in India to augment the supply as well as to control the demand for water. One of the demand management strategies introduced recently to control water consumption in Indian agriculture is drip method of irrigation (DMI). 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 1.1). 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, while the same is only about 35 to 40 percent for surface method of irrigation (INCID, 1994).

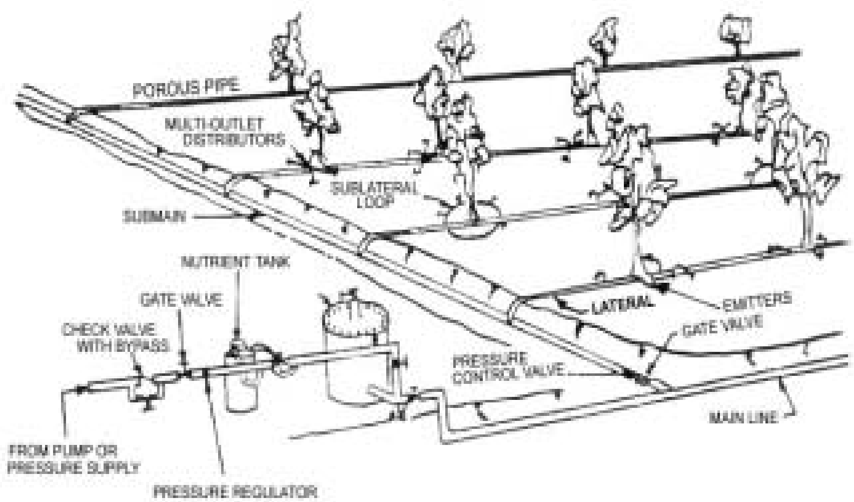


Figure 1.1 : Typical Drip Irrigation System

The development of drip method of irrigation has a long history. While the basic experiments has started way back in Germany in 1860s, an important breakthrough was achieved in Germany during 1920 when perforated pipe drip irrigation was introduced (INCID, 1994). Experiments carried out in the desert areas of Neger and Arava in Israel during early 1960s showed a spectacular results. The drip system with pipes began to be sold outside Israel on commercial basis in 1969. By the mid-1970s, farmers belonging to countries like Australia, Israel, Mexico, New Zealand and South Africa started using this new method of irrigation in crop cultivation (Postal, 1999). As per the worldwide survey carried out by the ICID, area under drip method of irrigation has increased from just 40 hectares (ha) in 1960 to about 54,600 ha in 1975 and further to about 1.78 million hectares in 1991 (INCID, 1994). According to a recent estimate, the global area under drip method of irrigation has likely expanded by 75 percent since 1991, which would be approximately 2.8 million hectares (Postal et al., 2001). While drip method of irrigation is currently practiced over 35 countries, the United States of America alone accounts for over 35 percent of the world's total drip irrigated areas (see, Dhawan, 2002). Surprisingly, in countries like Israel, Austria and Germany, all the irrigated areas are brought under micro-irrigation technology, due to its comparative advantages over FMI. Whereas micro-irrigation accounts for over 21 percent of the USA's total irrigated area, it accounts just 1.6 percent of India's total irrigated area. The significant growth of drip method of irrigation is attributable to higher crops productivity and water use efficiency including reduction in cost of cultivation. Studies carried out in countries like Israel, Jordan, USA and India have shown that drip method of irrigation increases crop productivity by 20-90 percent and reduces water use by 30-70 percent for different crops (Narayanamoorthy, 1997; Postal, 2001).

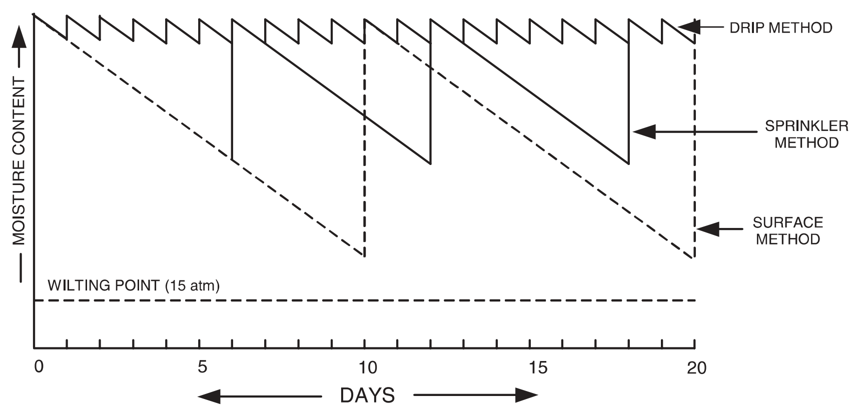
In India, though indigenous methods such as perforated earthenware pipes, perforated bamboo pipes, etc., were in practice for a long time, the modern drip system was introduced only during the early seventies at the Agricultural Universities and other Research Institutes. However, an appreciable improvement in the adoption of DMI has taken place only from the eighties, mainly because of various promotional programmes introduced by the Central and State governments. The area under DMI has increased from a mere 1500 ha in 1985 to 70,859 ha in 1991-92 and further to 5,00,000 ha as of March 2003 (INCID, 1994; GOI, 2004). India has enormous potential for DMI. INCID (1994) report, which presents an overview about the development of drip irrigation in India, indicates that about 80 crops, both narrow and widely spaced crops, can be grown under DMI. Although DMI is considered to be highly suitable for wide spaced and high value commercial crops, it is also being used for cultivating oilseeds, pulses, cotton and even for wheat crop (INCID, 1994). Importantly, research suggests that DMI is not only suitable for those areas that are presently under cultivation but it can also be operated efficiently in undulating terrain, rolling topography, hilly areas, barren land and areas which have shallow soils (Sivanappan, 1994).

Drip irrigation technology is introduced primarily to increase the water use efficiency in agriculture. However, 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, 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. The reduction in water consumption in drip method of irrigation also reduces the energy use (electricity) that is required to lift the water from irrigation wells (see, Narayanamoorthy, 1995, 2001).

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

Apart from water saving, which is the principal benefit of drip method of irrigation, it also helps to increase the productivity of crops mainly by reducing moisture stress for crops (see, Figure 1.2). Studies carried out based on experimental data suggest that the productivity of crops cultivated under DMI can be increased by 40 to 50 percent over the crops cultivated under FMI, especially in crops like bottle gourd, sweet potato, potato, tomato and chillies. Significant improvement in productivity of papaya (77 percent), banana (52 percent), grapes (23 percent), mosambi (50 percent) and pomegranate (98 percent) has also been reported by INCID (1994) and Sivanappan (1994).

Figure 1.2 : Moisture Availability for Crops in Different Irrigation Methods



Similar to vegetables and fruit crops, quite a few studies are available focusing on sugarcane crop, which is an important water-intensive crop. Most of the available studies in this respect have been carried out using the data supplied by the experimental research stations. Through the analysis of experimental data, studies have found a substantial water saving and productivity gains due to drip method of irrigation in sugarcane cultivation (Batta and Singh, 1998; Dash, 1998; Deshmukh, et al., 1998; Dhonde and Banger, 1998; Hapase, et al., 1992; Parikh et al., 1993; Sankpal, et al., 1998). Single cane weight, cane girth, cane length, number of internodes, leaf length and leaf breadth were also found to be higher with sugarcane cultivated under drip method of irrigation when compared to the same cultivated under flood method of irrigation (Venugopal and Rajkumar, 1998). Because of less moisture stress under DMI, the recovery rate of sugarcane cultivated under DMI was found to be higher when compared to the crop cultivated using FMI (Sankpal, et al., 1998; Dhonde and Banger, 1998; Banger, 1998).

Importantly, a study carried out on heavy soils and sub-humid climatic conditions of South Gujarat region suggests that a large scale adoption of drip method of irrigation in sugarcane in South Gujarat area can help to solve the problem of water logging and secondary salinization, which are increasing in this region (Parikh, et al., 1993).

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) indicate 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. However, it is not clear whether the B-C ratios presented in INCID (1994) are estimated using discounted cash flow technique or not. Unlike INCID estimates, using discounted cash flow technique and that too utilising field survey data covering three crops namely grapes, banana and sugarcane, Narayanamoorthy (1997, 2001 and 2004) estimated B-C ratio and net present worth. The results of these studies suggest that the investment in drip method of irrigation is economically viable even without subsidy. Obviously, the B-C ratio and NPW improves further when subsidy amount is taken for calculation.

However, in spite of having many economic advantages over the method of flood irrigation, the coverage of area under drip method of irrigation is not appreciable in India except for a few states as of today. Among the various reasons for the slow progress of adoption of this new technology, its capital-intensive nature seems to be one of the main deterrent factors. Drip irrigation technology requires fixed investment that varies from Rs. 20,000 to Rs. 55,000 per hectare depending upon the nature of crops (wide or narrow spaced) and the material to be used for the system. Since the Indian farmers have been getting water for low cost from the public irrigation system and also from well irrigation (because of the introduction of flat-rate electricity tariff), there is less incentive to them to adopt this capital-intensive technology unless it is necessary. Moreover, since it involves fixed investment farmers, often ask questions like what will be the water saving and productivity gains? Is investment on drip irrigation economically viable? What will be the pay back period of the drip investment? These issues are raised because of the following two reasons. First, the awareness of the farmers about this technology is very low due to poor extension service. Second, most of the studies available on drip irrigation in India is based on experimental data collected from different regions, which generally do not present the field level position (see, Verma and Rao, 1998; INCID, 1994; Dhawan, 2002). Some of the studies have shown that the results derived from research station data are substantially different from that of survey data (see, Narayanamoorthy, 2001). In the absence of reliable field studies, it is difficult to judge the actual economic viability of drip method of irrigation. It is in this context, an attempt is made in this paper to bring out the impact of drip method of irrigation on different economic parameters including economic viability using both secondary (experimental data) and field level data/information.

1.2 Objectives

1. To highlight the need for drip method of irrigation in Indian agriculture.

2. To study the coverage of drip method of irrigation across different states in India.

3. To analyse the impact of drip irrigation on water use pattern and water use efficiency in different crops.

4. To estimate the electricity saving due to drip method of irrigation in different crops.

5. To find out the economic viability of drip investment under with and without subsidy condition using different discount rates.

6. To estimate the macro potential area available for drip method of irrigation and the potential gains from the same for India as a whole.

7. To suggest policies to increase the widespread adoption of drip irrigation technology in India.

1.3 Data and Method

Drip method of irrigation is a new method of irrigation introduced relatively recently in Indian agriculture. Though significant development has taken place in the adoption of drip method of irrigation since early 1990s, not many studies are available based on field survey data on different crops. Most of the available studies are either based on experimental data or on the experience of one or few farmers adopting DMI. Therefore, the present study utilises both the secondary and primary level information on drip method of irrigation. The secondary information have been mainly collected from sources such as *Drip Irrigation in India* (published by the INCID, 1994), *Evaluation of Drip Irrigation System* (published by AFC,1998), the *Report of the Task Force on Micro Irrigation* (published by the Ministry of Agriculture, Government of India, 2004) and from the Commissionerate of Agriculture, Government of Maharashtra, Pune. In addition to this, information also collected from various published and unpublished sources wherever necessary.

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 (Narayanamoorthy, 1996, 1997 and Narayanamoorthy, 2001). In order to study the impact of DMI on different parameters in sugarcane cultivation, the study area and the sample selection has 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, in 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. In Maharashtra, farmers who are having own well (groundwater) are only using drip method of irrigation. Therefore, only those farmers who cultivate sugarcane 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 sugarcane. Since the state has structured scheme for promoting drip irrigation, the list of name of drip adopters pertaining to the year 1998-99 have been used for selecting the drip adopters. While the drip adopters were selected on the basis of random sampling method, the farmers who cultivate sugarcane 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 field level information from the sample farmers who have cultivated sugarcane 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 - were 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 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 for 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.

As underlined in the objectives, the impact of drip method of irrigation on parameters such as water use pattern including water saving, productivity of crops, electricity saving, etc., have been studied by comparing the same with the flood method of irrigation. How far the results of experimental data are different from the same derived from sample survey data is an issue in drip method of irrigation. This issue has been studied by comparing the experimental data with the field level data, especially in parameters such as productivity and water saving. One of the important issues pertaining to drip method of irrigation is whether or not the drip investment is economically viable. This question arises because DMI involves relatively large fixed investment. The past studies on this subject have conducted benefit-cost analysis without proper methodology, either relied on one or few farmers adopting DMI or estimated output-input ratio without considering life period of drip set, opportunity cost, depreciation factor, subsidy, etc. Therefore, in order to evaluate the economic viability of drip investment in three specific crops namely grapes, banana and sugarcane, we have computed the net present worth (NPW) and benefit cost ratio (BCR) by utilising the discounted cash flow technique[1]. Though drip method of irrigation has been followed in Indian agriculture since early 1980s, there seem to be no reliable information about the total potential area that is available for drip method of irrigation as well as the gross benefits that is possible from the drip method of irrigation for India as a whole. An attempt has been made to estimate the potential area for drip method of irrigation and benefits from the same using available secondary level information.

1.4 Organisation of the Study

The study has eight chapters including introductory chapter. The need for the drip method of irrigation is highlighted using mainly secondary information in chapter two. A detailed discussion on the development of drip irrigation across different States in India as well as its coverage in different crops is presented in chapter three. Since Maharashtra State accounts for nearly 50 percent of

1. The methodology and assumptions used for estimating the net present worth and the benefit-cost ratio are explained in detail in chapter six, where the subject of economic viability of drip investment is discussed elaborately.

India's drip irrigated area, an overview about its development has also been presented in the same third chapter. An analysis focusing on water saving and electricity saving due to drip method of irrigation is presented in chapter four. The impact of drip method of irrigation on cost of cultivation and productivity of different crops has been analysed using both experimental and field level data in chapter five. While chapter six presents a detailed analysis about the economic viability of drip investment under with and without subsidy condition using different discount rates, an estimate on the macro potential area for the drip method of irrigation including potential water saving for India as whole is presented in chapter seven. The last and final chapter provides summary of the study as well as policy recommendations for expanding the adoption of drip method of irrigation in India.

Chapter 2

Need for Drip Method of Irrigation

2.1 Introduction

The main objective of this chapter is to highlight the need for widespread adoption of drip method of irrigation in the context of Indian agriculture. As mentioned earlier, the discussion presented in this chapter is mainly based on secondary level information collected from different sources. Besides water saving and productivity gains, there are many justifiable reasons for promoting drip method of irrigation in countries like India, where available potential of water for irrigation has been declining at a faster rate. Broadly, we have identified six major reasons for adopting drip method of irrigation, which are associated with (a) water availability and management; (b) capital cost of irrigation; (c) production and productivity of crops; (d) electricity consumption; (e) environmental reasons and (f) extension of area under cultivation. Let us now discuss each of the reasons in detail.

2.2 Water Availability and Management

Considering the importance of irrigation in agricultural growth, prime attention has been given for the development of irrigation since independence in India. Up to 2001-02, about Rs. 1360.65 billion (in current prices) have been spent exclusively for the development of irrigation by the government sector alone (see, Table 2.1). As a result of this, area under irrigation has increased from 26.61 mha in 1950-51 to 86.67 mha in 1996-97, an increase of 2.60 percent per annum. Despite substantial increase of area under irrigation, the share of irrigated area to gross cropped area is only about 40 percent as of today. One of the main reasons for the limited expansion of area under irrigation is the predominant use of flood method of irrigation for cultivating crops, where water use efficiency is very low due to various reasons.

In India, the water use efficiency under flood method of irrigation is estimated to be only around 40 percent mainly due to huge losses through evaporation, conveyance and distribution (Sivanappan, 1994; Rosegrant, 1997; Rosegrant and Meinzen-Dick, 1996). Unlike FMI, water use efficiency can be achieved over 90 percent in DMI (see, Table 2.2). Since water is supplied directly to the root zone of the crops using pipe network under DMI, the evaporation and distribution losses are completely absent under this method. Though FMI has been followed predominantly all over the world for cultivating crops, it is no longer desirable for countries like India mainly due to limited availability of water resources and growing demand for water for irrigation and other purposes. Therefore, for achieving sustainable agricultural development, it is essential to increase the existing water use efficiency for which drip method of irrigation can be one of the viable options (Narayanamoorthy, 1997b).

Table 2.1 : Magnitude and Composition of Investment through Plan Periods in Irrigation and Flood Control Sectors

(Rs. Crore)

Plan	MMI	Minor Irrigation			C.A.D.	Flood Control	Total
		Public	Institu-tional	Total			
First (1951-56)	376.24	65.62	Neg.				
Second (1956-61)	380.00	142.23	19.35	161.58	—	48.06	589.64
Third (1961-66)	576.00	327.73	115.37	443.10	—	82.09	1101.19
Annual (1966-69)	429.81	326.19	234.74	560.93	—	41.96	1032.70
Fourth (1969-74)	1242.30	512.28	661.06	1173.34	—	162.04	2577.68
Fifth (1974-78)	2516.18	630.83	778.76	1409.58	—	298.61	4224.38
Annual (1978-80)	2078.58	501.50	480.40	981.90	362.96	329.96	3753.40
Sixth (1980-85)	7368.83	1979.26	1437.56	3416.82	743.05	786.85	12315.55
Seventh (1985-90)	11107.29	3118.35	3060.95	6179.30	1447.50	941.58	19675.67
Annual (1990-92)	5459.15	1680.48	1349.59	3030.07	619.45	460.64	9569.31
Eighth (1992-97)	21071.87	6408.36	5331.00	11739.36	2145.92	1691.68	36648.83
Ninth Plan (1997-02)*	48259.08	8615.07	2659.00	11274.07	1519.17	2629.23	63681.55
Total	100865.33	24307.90	16127.78	40435.67	6838.05	7485.91	155624.97

Note : * - anticipated: MMI - Major and Medium Irrigation; CAD - Command Area Development

Source : GOI (2002), *Tenth Five Year Plan: 2002-2007*, Vol. II, Planning Commission, Government of India, New Delhi.

Table 2.2 : Irrigation Efficiencies under Different Methods of Irrigation

(Percent)

Irrigation Efficiencies	Methods of Irrigation		
	Surface	Sprinkler	Drip
Conveyance efficiency	40-50 (canal) 60-70 (well)	100	100
Application efficiency	60-70	70-80	90
Surface water moisture evaporation	30-40	30-40	20-25
Overall efficiency	30-35	50-60	80-90

Source : Sivanappan (1998).

India has the largest irrigated area in the world, but its water potential available for the future use of irrigation has been declining at a rapid pace since independence owing to various reasons (Saleth, 1996). As per the estimate of the Central Water Commission (CWC, 1996), India's total irrigation potential is 139.9 mha. Of this total, about 58 mha (41.46 percent) can be utilised from major and medium irrigation (MMI) sources and about 81.40 mha (58.54 percent) can be utilised from minor irrigation (MI) sources. Up to 1999-2000, we have created about 94.73 mha of irrigated area, which accounts for about 67 percent of total potential (see, Table 2.3). Researchers have been cautioning that any additional creation of irrigation facility by constructing new major irrigation projects would not only require huge cost but would also create adverse environmental problems (Singh, 1997). However, considering the growth of population and the requirements of foodgrains in the future[2], there is a need to increase the area under irrigation. One of the options available before us is increasing the existing water use efficiency in all sources of irrigation. Though many programmes have been introduced to improve the existing water use efficiency under FMI, they could not bring desirable results so far[3]. It is possible to increase the existing water use efficiency as well as area under irrigation through drip method of irrigation as the requirement of water per hectare of cultivation is much less under this technology.

2. The Report of National Commission for Integrated Water Resources Development (1999) points out that India will require 320 million tonnes of foodgrains to feed 133.3 crore of population in the year 2025 and 494 million tonnes of foodgrains to feed 158.1 crore of population in the year 2050 (cited in Navalawala, 2001).

3. During the fifth five-year plan, Command Area Development Programme was introduced with the aim to reduce the gap between the irrigation potential created and utilised. However, this programme could not make any significant breakthrough in achieving its objectives and the gap between irrigation potential created and utilised has been increasing.

Table 2.3 : Irrigation Potential and Utilization in India: up to 1999-2000

Particulars	Potential	Created	Utilised	(3)/(2)x100	(4)/(3)x100
(1)	(2)	(3)	(4)	(5)	(6)
MMI	58.50 (41.82)	35.35	30.47	60.43	86.20
MI :					
(a) Surface	17.40 (12.44)	12.26	10.86	70.46	88.59
(b) Groundwater	64.00 (45.75)	45.59	41.93	71.23	91.97
(c) Total	81.40 (58.18)	59.38	54.23	72.95	91.33
Total (MMI + MI)	139.90 (100.0)	94.73	84.70	67.71	89.42

Notes: Figures in brackets are percentage to total;, MMI - Major and Medium Irrigation; MI - Minor Irrigation Sources: CWC (1998 and 2002); GOI (2001).

Table 2.4 : Statewise Position of Irrigation Potential Created and Utilised upto the Ninth Plan

Sr. No.	Name of State & UTs	Ultimate Irrigation Potential: MMI	MMI Potential Created till end of IX Plan	MMI Potential utilised till end of IX Plan	Percent of Column (4) to (3)	Ultimate Irrigation Potential: MI	MI Potential Created till end of IX Plan	MI Potential Utilised till end of IX Plan	Percent of Column (7) to (6)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
1	Andhra Pradesh	5000.00	3303.22	3051.59	66.06	6260.00	3019.46	2781.22	48.23
3	Assam	970.00	243.92	174.37	25.15	1900.00	603.62	494.11	31.77
4	Bihar	5223.50	2680.00	1714.83	51.31	5663.50	4716.44	3759.46	83.28
5	Jarkhand	1276.50	354.47	230.45	27.77	1183.50	588.87	471.09	49.76
6	Goa	62.00	21.17	15.33	34.15	54.00	19.14	20.00	35.44
7	Gujarat	3000.00	1430.37	1300.83	47.68	3103.00	1998.92	1876.14	64.42
8	Haryana	3000.00	2099.49	1849.97	69.98	1512.00	1630.95	1578.12	107.87
9	Himachal Pradesh	50.00	13.35	7.51	26.70	303.00	161.00	138.30	53.14
10	Jammu & Kashmir	250.00	179.69	168.75	71.88	1108.00	382.45	366.77	34.52
11	Karnataka	2500.00	2121.12	1844.82	84.84	3474.00	1585.40	1541.74	45.64
12	Kerala	1000.00	609.49	558.87	60.95	1679.00	640.02	603.76	38.12
13	Madhya Pradesh	4853.07	1386.90	875.63	28.58	11361.00	2256.13	2149.48	19.86
14	Chattisgarh	1146.93	922.50	760.74	80.43	571.00	487.70	322.86	85.41
15	Maharashtra	4100.00	3239.00	2147.24	79.00	4852.00	2942.60	2557.72	60.65
20	Orissa	3600.00	1826.56	1794.17	50.74	5203.00	1474.12	1337.55	28.33
21	Punjab	3000.00	2542.48	2485.99	84.75	2967.00	3427.56	3367.82	115.52
22	Rajasthan	2750.00	2482.15	2313.87	90.26	2378.00	2447.10	2361.80	102.91
24	Tamil Nadu	1500.00	1549.31	1549.29	103.29	4032.00	2123.38	2119.52	52.66
26	Uttar Pradesh	12154.00	7910.09	6334.00	65.08	17481.00	21599.40	17279.62	123.56
27	Uttaranchal	346.00	280.30	185.41	81.01	518.00	500.98	400.80	96.71
28	West Bengal	2300.00	1683.29	1527.12	73.19	4618.00	3792.52	3098.12	82.12
	UTs.	98.00	6.51	3.94	6.64	46.00	43.71	35.41	95.02
	Total	58180.00	36885.38	30894.72	63.40	80267.00	56441.47	48661.41	70.32

Source: Same as in Table 2.1.

The irrigation potential available for future use has also been declining in many states. In fact, the condition is precarious in agriculturally advanced states like Punjab, Haryana and Tamil Nadu (see, Table 2.4). The irrigation potential created to the total potential of MMI up to the ninth plan ranges from 69 to 103 percent in states like Haryana, Punjab and Tamil Nadu. Similarly, the irrigation potential created to the total potential of MI also varies from about 53 percent to 123 percent in states like Haryana, Punjab, Rajasthan, Gujarat, Maharashtra, Tamil Nadu and Uttar Pradesh (see, Narayanamoorthy, 2002). Further exploitation of water through MMI and MI sources from these states certainly would create adverse environmental problems. Therefore, cultivating crops with the present method of irrigation, i.e., flood method of irrigation, is no longer desirable. Besides solving the problem of over-exploitation of water, the drip method of irrigation helps to increase the area under irrigation by saving substantial amount of water (Narayanamoorthy, 1997).

Table 2.5 : Statewise Groundwater Potential and Development

(cubic km/year)

Sr. No.	States	Total Repleni-shable Ground-water Reserve Uses	Provision for Do-mestic, Indus-trial & other	Available Ground-water Resour-ces for Irrigation	Net Draft	Balance Ground-water Potential available for Exp-loitation	Level of Ground water Develop-ment (percent)
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1.	Andhra Pradesh	35.29	5.29	30.00	7.09	22.91	23.64
2.	Assam	24.72	3.71	21.01	0.94	20.07	4.48
3.	Bihar	33.52	5.03	28.49	5.47	23.03	19.19
4.	Gujarat	20.38	3.06	17.32	7.17	10.15	41.45
5.	Haryana	8.53	1.28	7.25	6.08	1.17	83.88
6.	Himachal Pradesh	0.37	0.07	0.29	0.05	0.24	18.10
7.	Jammu & Kashmir	4.43	0.66	3.76	0.05	3.71	1.33
8.	Karnataka	16.19	2.43	13.76	4.30	9.46	31.26
9.	Kerala	7.90	1.31	6.59	1.01	5.58	15.28
10.	Madhya Pradesh	50.89	7.63	43.26	7.13	36.12	16.49
11.	Maharashtra	37.87	12.40	25.47	7.74	17.73	30.39
12.	Orissa	20.00	3.00	17.00	1.43	15.57	8.42
13.	Punjab	18.66	1.87	16.79	15.76	1.03	93.82
14.	Rajasthan	12.71	1.99	10.71	5.42	5.29	50.63
15.	Tamil Nadu	26.39	3.96	22.43	13.56	8.87	60.44
16.	Uttar Pradesh	83.82	12.57	71.25	26.84	44.41	37.67
17.	West Bengal	23.09	3.46	19.63	4.75	14.88	24.18
	All States	431.48	70.74	360.74	115.01	245.73	31.88
	All UTs.	0.41	0.19	0.21	0.17	0.06	76.19
	All India	431.89	70.93	360.96	115.17	245.79	31.92

Note : Total may not tally due to rounding off figures. Source: CWC (1998).

Similar to surface irrigation sources, the available groundwater for the use of irrigation has also been steadily declining in most of the agriculturally advanced states. The New Agricultural Technology (NAT) introduced during the mid-sixties has significantly increased the demand for irrigation water, which ultimately resulted in over-exploitation of groundwater in many parts of India. Again the principal reason for the over-exploitation of groundwater is the predominant cultivation of water-intensive crops under flood method of irrigation. A recent state-wise estimate on groundwater potential and utilisation has shown that the use of groundwater is going beyond the socially acceptable limit in many agriculturally advanced states (see, Table 2.5). As a result of this, there is a tremendous pressure on water resources than ever before, but the quantum of available water is fast declining. Since water saving under DMI is substantial, the problem of over-exploitation can be easily restricted when the same is adopted extensively.

Table 2.6 : Development of Irrigation Potential (cumulative) through Plan periods

(mha)

Plan	Major/Medium Irrigation		Minor Irrigation		Total Irrigation		Gross Irrigated Area as per LUS
	Potential	Utilisation	Potential	Utilisation	Potential	Utilisation	
1	2	3	4	5	6	7	8
Pre-Plan	9.70	9.70	12.90	12.90	22.60	22.60	22.56
First (1951-56)	12.20	10.98	14.06	14.00	26.26	25.04	25.64
Second (1956-61)	14.33	13.05	14.75 (8.28)	14.75 (8.28)	29.08	27.80	27.98
Third (1961-66)	16.57	15.17	17.00	17.00	33.57	32.17	30.9
Annual (1966-69)	18.10	16.75	19.00 (12.50)	19.00 (12.50)	37.10	37.75	35.48
Fourth (1969-74)	20.70	18.69	23.50 (16.44)	23.50 (16.44)	44.20	42.19	40.28
Fifth (1974-78)	24.72	21.16	27.30 (19.80)	27.30 (19.80)	52.02	48.46	46.08
Annual (1978-80)	26.61	22.64	30.00 (22.00)	30.00 (22.00)	56.61	52.64	49.21
Sixth (1980-85)	27.70	23.57	37.52 (27.82)	35.25 (26.24)	65.22	58.82	54.53
Seventh (1985-90)	29.92	25.47	46.61 (35.62)	43.12 (33.15)	76.53	68.59	61.85
Annual (1990-92)	30.74	26.32	50.35 (38.89)	46.54 (36.25)	81.09	72.86	65.68
Eighth (1992-97)	32.96	28.44	53.30	48.80	86.26	77.24	70.64
Ninth Plan (1997-02)*	37.08	31.03	56.90	49.05	93.98	80.80	

Note: * - anticipated; Figures in brackets are groundwater area. Source: Same as in Table 2.1.

2.3 Capital Cost of Irrigation

As mentioned earlier, a massive investment has been made exclusively for the irrigation development in India by the public sector alone. As a result of massive investment on irrigation, the total area under irrigation has increased from 22.61 mha in the pre-plan period (1950-51) to 86.26 mha in 2001-02 (see, 2.6). Though the massive investment on irrigation was justified by many experts in view of the nature of the Indian economy, capital cost required to create one hectare of irrigation has increased substantially, especially after the fifth five-year plan. For instance, the requirement of investment (in current prices) for creating one hectare of irrigation in MMI sector was only Rs. 1513 in first five-year plan, but the same increased to over Rs. 2,37,729 in 2001-02 (Narayanamoorthy, 1995; Narayanamoorthy and Kalamkar, 2004).[4] One of the main reasons attributed for the huge increase in the requirement of investment per hectare is that the new irrigation projects are more capital intensive, as most of the easily available potential has already been exploited (Vaidyanathan, 1999; Gulati, et al., 1994).[5] Besides involving higher financial investment, the major irrigation projects are also capable of creating many social and environmental problems (Singh, 1997; Rosegrant, 1997).[6] Though drip method of irrigation is a capital-intensive technology, its capital requirement per hectare is relatively less when compared to the same required for MMI projects. In addition to this, the operation and maintenance costs of MMI projects have also been increasing due to various reasons (Gulati, et al., 1994). Though drip irrigation cannot be a substitute for MMI projects, the cost related problems that are associated with the large irrigation projects, could be reduced to some extent by adopting drip method of irrigation at a large scale.

Apart from the issues associated with capital cost, the financial performance of the irrigation sector in India is also not in good condition. According to Vaidyanathan Committee Report on Pricing of Irrigation Water (GOI, 1992), the revenue collected from MMI projects

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4. See, Gulati, et al., (1994) for more details regarding the cost and financial aspects of Indian irrigation.

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

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

is not even enough to meet the operation and maintenance cost of the irrigation system. While the revenue was covering about 25 percent of the operation and maintenance cost in 1977-78, the same declined to a meagre 9 percent by 1986-87. Recent data (1998-99) also show that the percentage of recovery of working expenses through gross receipts in irrigation and multipurpose river valley projects is only 6.30 percent (CWC, 1998 and 2002). This poor financial performance of irrigation sector has been observed even in States like Maharashtra, where not only the water rates are revised periodically but water rates for different crops are also very high compared to other States (Deshpande and Narayanamoorthy, 2001; Narayanamoorthy and Kalamkar, 2004). The main reason behind the poor financial recovery is the continuous increase of operation and maintenance expenditures of irrigation projects. Even after spending huge amount of money for system maintenance, the water use efficiency is very less in most of the canal command areas (see, Vaidyanathan, 1999; GOI, 1994)). The Command Area Development Programme, which was introduced mainly to increase the efficiency of water use in the command area and to bridge the prevailing gap between potential created and utilised in MMI projects, could not succeed in its objectives. This has brought tremendous pressure on the investment in irrigation and a large part of this investment does not even yield the minimum expected return today. Though drip method of irrigation cannot be an alternative to the mega projects, a large-scale adoption of drip-irrigated technology can partially solve the problems associated with cost recovery.

2.4 Production and Productivity

Although the introduction of new agricultural technology has helped to increase production of foodgrains impressively from about 72 million tonnes in 1965-66 to over 211 million tonnes in 2001-02, the achievement in production of non-foodgrain commodities such as oilseeds, vegetables, fruits, etc, is not very impressive (Kumar and Mathur, 1996).[7] Despite various efforts made by the policy makers, production (supply) of non-foodgrains is much less when compared to the domestic requirements (demand) as estimated by a recent study (Kumar and Mathur, 1996). This has forced the government to import these commodities from other countries to meet the domestic requirements. Since most of the non-foodgrain crops mentioned

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

above are cultivated predominantly under rain-fed condition where moisture stress is common, production of these commodities could not be increased to the desired level. Unlike FMI, the crops cultivated under DMI do not face any moisture stress as water is supplied on a continuous basis at a required level. The yield increasing inputs (fertilisers, etc.,) applied for crops cultivated under flood method of irrigation also do not fully reach the crops due to leaching and other reasons. As fertilisers (liquid) can be supplied through water (which is called fertigation), the loss of fertilisers by way of leaching and evaporation is very less and hence high-level input use efficiency is possible under DMI. Since both moisture level and input use efficiency are maintained at a higher level under drip method of irrigation, productivity of crops cultivated under drip method of irrigation is significantly higher than the crops cultivated under FMI.

Further, the production of foodgrains and other agricultural commodities have to be increased keeping in view the growth of population. Already, the growth in foodgrains productivity was very low during the nineties (1.52 percent per annum) when compared to the growth of eighties (2.74 percent per annum) (see, Table 2.7). Our experience indicates that production of foodgrains also goes down sharply whenever fluctuations occur in rainfall. In order to avoid this problem, new areas with irrigation facility need to be brought under cultivation. As mentioned earlier, creating irrigation facilities through MMI projects would cost more for the exchequer and also take long gestation period. With the available irrigation potential, the area under irrigation can be expanded further if drip method of irrigation is followed, as it requires less water when compared to flood method of irrigation[8].

2.5 Energy Saving

Due to rapid development of groundwater irrigation in Indian agriculture, the requirement of electricity for agriculture (used for irrigation pumpsets) has increased significantly since the introduction of green revolution. For instance, between 1965-66 and 1995-96, while the total (all sectors) consumption of electricity has increased at a rate of 8.12 percent per annum, the same increased at a rate of 13.56 percent per annum in agricultural sector (Narayanamoorthy, 1999). In absolute term, consumption of electricity in agricultural

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

Table 2.7 : Compound Growth-Rate of Area, Production and Yield of Principle Crops in India (Base: TE 1981-82=100)

(Percent per annum)

Crop	1949-50 to 2001-02*			1949-50 to 1964-65			1967-68 to 2001-02*			1980-81 to 1989-90			1990-91 to 1999-2000		
A	P	Y	A	P	Y	A	P	Y	A	P	Y	A	P	Y	
Rice	0.75	2.66	1.90	1.21	3.50	2.25	0.62	2.78	2.20	0.41	3.62	3.19	0.62	1.90	1.27
Wheat	2.08	5.26	3.12	2.69	3.98	1.27	1.38	4.34	2.92	0.46	3.57	3.10	1.67	3.81	2.11
Jowar	-2.78	-1.61	1.48	0.99	2.51	1.49	-1.71	-0.11	1.62	-0.99	0.28	1.29	-3.71	-3.59	0.12
Bajara	-0.27	1.60	1.88	1.08	2.34	1.24	-0.92	1.02	1.96	-1.05	0.03	1.09	-1.58	0.60	2.21
Coarse Cereals	-0.69	0.99	1.57	0.90	2.25	1.23	-1.44	0.54	1.90	-1.34	0.40	1.62	-0.54	1.48	-0.08
Total Cereals	0.41	2.85	2.05	1.25	3.21	1.77	-0.02	2.77	2.32	-0.26	3.03	2.90	-0.08	2.10	1.58
Gram	-0.66	0.06	0.72	1.64	2.66	1.00	-0.58	0.13	0.71	-1.41	-0.81	0.61	1.22	3.31	2.06
Tur	0.94	0.83	-0.10	0.57	-1.34	-1.90	1.21	1.24	0.03	2.30	2.87	0.56	-0.65	0.04	0.69
Other Pulses	0.39	0.91	0.52	2.06	1.28	-0.77	0.07	1.26	1.19	0.02	3.05	3.03	-1.60	-1.39	0.21
Total Pulses	0.10	0.54	0.48	1.72	1.41	-0.18	0.30	0.81	0.74	-0.09	1.52	1.61	-0.61	0.61	0.96
Total foodgrain	0.35	2.48	1.78	1.35	2.82	1.36	0.01	2.51	2.12	-0.23	2.85	2.74	-0.17	1.94	1.52
Sugarcane	1.84	3.05	1.19	3.28	4.26	0.95	1.81	3.07	1.24	1.44	2.70	1.24	1.81	2.78	0.95
Groundnut	0.79	1.61	0.82	4.01	4.34	0.31	0.15	1.23	1.09	1.67	3.76	2.06	-2.25	-1.22	1.06
R & M	2.05	4.19	2.10	2.97	3.35	0.37	2.23	4.87	2.58	1.95	7.28	5.22	1.66	1.95	0.29
Nine Oilseeds	1.40	2.78	1.23	2.53	3.12	0.00	1.63	3.41	1.71	2.47	5.36	2.49	0.66	1.98	1.49
Total Oilseeds	2.78	1.23	1.20	2.67	3.20	0.30	1.31	3.32	1.60	1.51	5.20	2.43	1.14	2.13	1.25
Cotton	0.34	2.47	2.12	2.47	4.55	2.04	0.35	2.57	2.21	-1.25	2.80	4.10	2.36	1.73	-0.61
Total Fibers	0.30	2.31	1.98	2.71	4.56	1.88	0.24	2.44	2.15	-1.50	2.46	3.98	2.16	1.74	-0.46
Non Foodgrains	1.26	2.96	1.36	2.44	3.74	0.89	1.36	3.20	1.68	1.12	3.77	2.31	1.37	2.78	1.04
All Principle Crops	0.57	2.66	1.68	1.58	3.15	1.21	0.34	2.78	1.90	0.10	3.19	2.56	0.25	2.28	1.31

Notes: A - Area; P - Production; Y - Yield; * - Provisional; Nine oilseeds includes groundnut, castor seed, sesamum, rapeseed & mustered, linseed, niger seed, safflower, sunflower & soyabean; Total oilseeds include nine oilseeds plus cottonseed and coconut.

Source: GOI (2002).

sector has increased from 1,982 million kwh in 1965-66 to 91,277 million kwh in 1997-98. No doubt that the contribu-tion of ground-water irrigation to the total production and producti-vity of crops in Indian agriculture is substantial (Moench, 1994; Shah, 1993; Shah and Roy, 2004). However, the researchers have been arguing that both water and electricity are used most inefficiently in many parts of groundwater regions because of cheaper pricing policy (either free of cost or under flat-rate tariff system) that is followed for agricultural purpose (Vaidyanathan, 1999; 1997). Although it is difficult to conclude that the cheaper tariff has redu-ced the efficiency of water use in agriculture (Moench and Kumar, 1997; Narayanamoorthy, 1997), it has certainly affected the financial position of the State Electricity Boards (SEBs). One of the main reasons for the huge increase of electricity consumption in agriculture is the predominant use of flood method of irrigation that too for water-intensive crops like sugarcane, banana, etc. Since water saving from DMI is substantial, a large-scale adoption of drip method of irrigation would help in reducing the subsidy amount given to agricultural sector on account of electricity. A field level study carried out in this context in Maharashtra estimated that electricity saving due to DMI was about 2430 kwh/ha for banana and 1470 kwh/ha for grapes (Narayanamoorthy, 1996a).

2.6 Environmental Reasons

In recent years, the environmental problems associated with irrigation have been increasing at a rapid pace in Indian agriculture (Chopra, 1996). Most of the environmental problems occur mainly because of the predominant practice of the flood method of irrigation. The conventional method of irrigation not only leads to inefficient use of irrigation water due to enormous losses in evapora-tion and distribution, but also results in over-use of water which ultimately brings many negative externalities in agriculture. While the over-use of irrigation water causes damage to soils in the form of water logging and soil salinity on the one side, it also reduces the yield of crops on the other side (Chopra, 1996). Groundwater irriga-tion also has its own share of problems although the magnitude is different from MMI system. With the fast increase of density of wells, the rate of exploitation of groundwater has been increasing at a rapid pace. As a result of over-exploitation of water, problems like sea water intrusion, progressive lowering of water table, increase in fluoride level in groundwater, etc., have been reported in different parts of the country (Vaidyanathan, 1994).

According to an estimate of Central Water Commission (1996), about 141 mha out of 329 mha of geographical area is subject to water and wind erosion. In addition to this, about 34 mha is affected by land degradation problems like water logging, alkaline and acidic soil, salinity, ravines and gullies, shifting cultivation, riverine and torrents etc. Only about 47 percent of the total geogra-phical area can be considered as unaffected land resources. The major causes for land degradation are water logging and salinity and estimates indicate over 40 percent of the land area is affected by such problems (CWC, 1996). Out of 8.5 mha of the land affected by water logging in the country, nearly 2.46 mha is estimated to be caused by the inadequate drainage system in the command areas. Similarly, out of 5.5 mha of the land affected by salinity, as much as 3.06 mha comprises of the area affected due to irrigation related problems (CWC, 1996). Maximum problems of water logging is reported to be concentrated in the States of Bihar, Uttar Pradesh, Andhra Pradesh, Haryana and Punjab which account for nearly three-fourth of the total area affected in the irrigation commands in the country (CWC, 1996). According to various studies, the main reason for water logging is the over-use of irrigation and negligence of drainage part of the irrigation system (Vaidyanathan, 1994).

A study carried out in Gujarat (coastal areas of Saurashtra region) showed how adversely the over-exploitation of groundwater has affected the land resources. Tube-wells development in these areas shifted the crop pattern from food crops to sugarcane to a larger extent. As a result of this, the water table in this region fell by 3-10 meters over a period of seven or eight years. In 1970, majority of the farmers in this area suffered reduced crop yields and found well water brackish; some farmers continued to irrigate with the saline water thereby ruining their top soils. In fact, the unfettered exploitation of groundwater in this region impound largely irreparable damage on land resources and affected a large number of families (Shah, 1993). The main reason for all these problems is predominant use of flood method of irrigation where controllability of irrigation water is very less. Drip method of irrigation would help to reduce the environmental problems associated with flood method of irrigation to a larger extent, as the management of irrigation is much easier under DMI. Moreover, since water is supplied at the root zone of the crop at a required quantity with required interval, water logging is completely absent under DMI.

2.7 Area under Cultivation to be Expanded

Considering the growth of population in India as well as requirement of various agricultural commodities, it is necessary to bring new area under cultivation. The net sown area of the country is almost constant for the last 30 years, as all the productive lands have already been brought under cultivation.[9] Most of the unutilized areas are available in the form of undulating terrain and hilly areas,

Table 2.8 : Comparative Advantages of Drip Irrigation over Flood Irrigation

	Variables	Drip Method	Flood Method
1.	Water saving	40-100 percent	Less owing to evaporation losses
2.	Irrigation efficiency	80-90 percent	30-50 percent
3.	Input cost	Less especially in labour, fertilizers, pesticides and tilling	Comparatively higher
4.	Weed problem	Reduced significantly	Very High
5.	Suitable water	Even saline water can be used	Only normal water can be used
6.	Diseases and pest problems	Relatively less	High/moderate
7.	Water logging	Nil	About 8.5 mha is under water logging in India
8.	Water control	Easily manageable	Difficult to manage
9.	Evaporation and transportation losses	Very low	Very High
10.	Labour requirement	Relatively low	High
11.	Efficiency of fertiliser use	Very high and constant supply	Heavy losses owing to leaching and evaporation
12.	B-C ratio	Excluding water saving: 1.3-13.3 including water saving: 2.8-30.0	In the range of 1.8-3.9
13.	Capital cost/ha	Rs. 15000-40000 varies with space and crops	Rs. 70000 for MMI projects during 7th Plan
14.	Product quality	Relatively better	Normal
15.	Increase in yield	About 20-100 percent higher vis-à-vis flood method	Yield is less compared to drip irrigation

Source : Narayanamoorthy, (1997a).

9. The net sown area of the country, between 1970-71 and 1996-97, has increased about 2.55 mha with a compound growth rate of only 0.07 percent per annum (GOI, 2000). Virtually all the easily possible productive lands have already been brought under cultivation.

which are not suitable for crop cultivation under flood method of irrigation. However, unlike flood method of irrigation, drip method of irrigation can be operated in all types of areas: undulating terrain, rolling topography, hilly areas, shallow soils, saline water areas as well as water scarce areas. As per the land use data of 1996-97, about 56.25 mha of area was available in the form of fallow, cultivable waste, barren land, etc. Large part of this area can be brought under drip method of irrigation and handed over to the poor and landless labourers under participatory irrigation management (PIM). This would not only help to increase the area under irrigation with less investment, but would also reduce the level of poverty that prevails in rural India in a sustained manner.

In addition to the reasons discussed above, drip method of irrigation also helps to improve the quality of produce, efficiency in fertiliser application, reduces weed growth, saves labour costs, etc (see, Table 2.8). On the whole, it is clear from the above that it is possible to reduce the problems associated with demand-supply position of water, cost of irrigation, financial position of irrigation sector, environment, etc., by adopting drip method of irrigation at a large scale.

Chapter 3

Development of Drip Irrigation in India

3.1 Introduction

Though drip method of irrigation is relatively a new method of irrigation introduced in Indian agriculture, substantial development has taken place in the adoption of this new irrigation technology over the last fifteen years. In this section, besides discussing the development of drip irrigation across different States as well as across different crops, we also present the efforts made by the government (including some State governments) for promoting drip method of irrigation in Indian agriculture. Since the adoption of drip method of irrigation is relatively well developed in Maharashtra State, a detailed account about its development over the years has also been presented at the end of this chapter[10].

3.2 Promotional Activities on Drip Irrigation in India

Drip method of irrigation was introduced in India during the early seventies at the Agricultural Universities and other Research Institutions. The scientists at the Tamil Nadu Agricultural University (TNAU), Coimbatore, who are considered to be the pioneers in drip irrigation research in India, have conducted large-scale demonstration in the farmers' field for various crops, which received encouraging response from the farmers (INCID, 1994). However, the adoption of drip method of irrigation was very slow till mid-eighties mainly because of lack of promotional activities from the State and Central governments.

The formation of the National Committee on the Use of Plastics in Agriculture (NCPA) by the Ministry of Petroleum, Chemicals and Fertilisers, Government of India, during 1981 under the Chairmanship of Dr. G.V.K. Rao is termed as the first milestone for the development of micro-irrigation in India (GOI, 2004). With the establishment of 17 different Plasticulture Development Centres

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10. Similar to Maharashtra State, Andhra Pradesh has also introduced a State level scheme to promote micro irrigation, which is known as Andhra Pradesh Micro Irrigation Project (APMIP). This project was introduced during November 2003 and is aiming to cover 2.50 lakh hectares during the next three years. Due to non-availability of data about its progress, we could not include any details about the development APMIP in this report.

(PDCs) across different agro-climatic regions in the country, the NCPA has played a crucial role in the technological development of micro-irrigation in India.[11] Besides recommending policy measures to the government, the NCPA also played an important role in promoting drip method of irrigation through conducting seminar focusing on micro-irrigation (GOI, 2004).

Apart from the government efforts, some research institutes and private drip set manufactures have also been playing an important role in promoting drip method of irrigation in India. For instance, The Report of Task Force on Micro Irrigation rightly mentions "Jain Irrigation Systems Ltd., Jalgaon has been playing a pioneering role since its inception in 1989 for promoting micro irrigation" (GOI, 2004, p. 124). The establishment of the Jain Irrigation Systems Limited in 1988-89 marked a watershed in the spread of this technology. Their approach was unique, committed, scientific and persistent. A "Systems approach" from concept to commissioning was adopted by them. Learning from the mistakes and the short comings of the past, this new company undertook extensive surveys in the market, interacted with scores of customers who had installed drip irrigation systems in their field, critically evaluated its ills and took systematic and determined steps to remove these ills. The concept in fact was pioneered in the country by the Jain Irrigation, Jalgaon. A decade ago, the company established 600 acres agro related Research & Development Farm at Jalgaon, where experiments on various aspects related to agronomy, irrigation, water management, water-shed and waste land development are conducted on regular basis. Farmers can see for themselves on this farm the advantages of adopting modern and innovative technologies and put these concepts into practice on their farmlands (see, AFC, 1998; GOI, 2004).

3.3 Schemes for Drip Irrigation

Since drip irrigation is a new technology and a capital-intensive venture, government operates schemes for drip irrigation with subsidy. In states like Maharashtra, both the Central and State governments are operating schemes for promoting drip method of irrigation. Central scheme was started during 1982-83 (during the Sixth Plan) by the Ministry of Water Resources (Minor irrigation Division), Government of India. Through this scheme, the Government of India provided a subsidy of 50 percent to the farmers with the

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

matching contribution from the State governments for installation of micro-irrigation devices. Of the total amount of subsidy, 75 percent was allocated for small and marginal farmers and the balance of 25 percent for other group of farmers. Government of Maharashtra has made pioneering efforts for the successful adoption of drip irrigation system and to make cost effective by providing subsidies to small and marginal farmers to the extent of Rs. 2282.35 lakh during the period from 1986-93 (INCID, 1994).

Central scheme of drip irrigation was also introduced during the Seventh Plan with the following modifications :

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

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

(c) The percentage of subsidy eligible under the scheme was at par with the on-going Integrated Rural Development Programme.

(d) Farmers growing horticultural crops like grapes, papaya, arecanut and coconut were also eligible for subsidy.

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

However, the Central scheme of drip irrigation did not get good response during the Seventh Plan since the subsidy was limited to small and marginal farmers only and due to capital paucity this group could not afford the drip systems even at the subsided rate. After knowing the ground realities, many new measures were incorporated under the new scheme introduced during the eighth plan. Under the new schemes, the subsidy amount is limited to either 50 percent of the cost or Rs. 15000/ha whichever is lower. The government of India has contributed the entire 50 percent of subsidy upto the financial year 1994-95 and thereafter the State governments have to contribute 10 percent towards subsidy for the years 1995-96 and 1996-97, which will add upto 50 percent with Centre's contribution for 40 percent. However, a beneficiary can avail subsidy for a maximum area of one hectare only.

The subsidy scheme has undergone lot of changes over the years. As of 1999-2000, the Government of India provided assistance of drip installation for horticultural crops at 90 percent of the cost of the system or Rs. 25000 per hectare, whichever is less for small and marginal, SC/ST and women farmers and 70 percent of the total cost or Rs. 25000 per hectare, whichever is less for other category of farmers. Assistance was also provided for drip demonstration at Rs. 22500 or 75 percent of the system cost per hectare whichever is less (GOI, 2004).

Government of Maharashtra has also been providing subsidy under State schemes since 1986-87. It varies from 30 to 50 percent of the capital cost or Rs. 12250 to 20500/ha depending upon the landholding size and community of the farmers. The Government of Maharashtra announced in 1992 that subsidy would be given for all farmers irrespective of their landholding. That is, currently both the schemes (Central and State sponsored schemes) supply 50 percent of the capital cost as subsidy for all types of farmers in Maharashtra.

3.4 Coverage of Drip Irrigation in India

Drip method of irrigation was initially introduced in the early seventies by the agricultural universities and other research institutions in India with the aim to increase the water use efficiency in crop cultivation. The development of drip irrigation was very slow in the initial years and significant development has been achieved especially since 1990s. Due to various promotional schemes introduced by the Government of India and states like Maharashtra, area under drip method of irrigation has increased from 1500 ha in 1985 to 70589 ha in 1991-92 and further to 246000 ha in 1997-98 (INCID, 1994; AFC, 1998). According to the latest information, the area under DMI estimated to have been increased to about 4.50 lakh hectares, which includes about 3.50 lakh hectares covered under the Government of India Schemes (GOI, 2004, p. 130). This estimate is based on the information available from GOI depart-ments, which have been operating subsidy schemes for promoting drip method of irrigation. However, as mentioned in the Report of the Task Force on Microirrigation, a large number of institutions, commercial organisations, universities, large public/private sector companies, NGOs, etc., have taken up drip irrigation in the country for their farms/crops, which do not get reflected in the data avai-lable with GOI departments. Therefore, approximately, another 1,00,000 hectares are covered under drip systems by these organisations, whereby the total area under drip irrigation systems in the country would be about 5,00,000 hectares as of March 2003 (GOI, 2004, pp. 130-131).

Table 3.1 : Statewise Area under Drip Method of Irrigation

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

Notes : a - includes state subsidy scheme area of 58498 ha.
b - includes area under central and state schemes for development of oil palm and sugarcane.

Sources : AFC (1998) and GOI (2004).

Despite having enormous potential and prospects, the develop-ment of drip irrigation does not match the expectations in most of the states. Table 3.1 presents state-wise area under drip method of irrigation for three time points: 1991-92, 1997-98 and 2000-01. It is evident from the table that drip irrigated area has increased substantially between 1991-92 and 2000-01 in all the states of India. In all three-time points, Maharashtra state alone accounted for nearly 50 percent of India's total drip irrigated area followed by Karnataka, Tamil Nadu and Andhra Pradesh.[13] Over the last ten years, significant growth has been

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

achieved in area under drip method of irrigation in absolute term in many states. However, drip irrigated area constitutes a very meagre percentage in relation to gross irrigated area in all the states in India. For instance, during 2000-01, the share of drip-irrigated area to gross irrigated area was just 0.48 percent and about 1.09 percent in relation to total ground-water irrigated area of the country.

3.5 Crop-wise Coverage of Drip Method of Irrigation

As mentioned earlier, although over 80 crops are suitable for drip method of irrigation, only a few crops have been dominating in the total area under drip irrigation so far. As of 1997-98, crops like coconut, grapes, banana, citrus, mango and pomegranate together have accounted for nearly 67 percent of total drip irrigated area (see, Table 3.2). In all these crops, states like Maharashtra, Andhra Pradesh, Tamil Nadu and Karnataka account for a major share of the area. More importantly, out of 26,460 ha of banana's total area, Maharashtra state alone accounted for as much as 93 percent at the end of 1997-98. It clearly suggests that despite having severe water scarcity in different regions in the country, the adoption of drip method of irrigation is very much concentrated only in a few States. If we really want to avoid aggravating supply-demand gap in irrigation water in the future, it is essential to bring more water-intensive crops under drip method of irrigation.

Table 3.2 : Crop-wise Area under Drip Method of Irrigation in India: 1997-98

Crop's Name	Area	Leading States
Coconut	48360 (19.66)	Karnataka (24.00, Tamil Nadu (21.20)
Grapes	29630 (12.04)	Maharashtra (24.10), Andhra Pradesh (2.20), Karnataka (3.00)
Banana	26460 (10.76)	Maharashtra (24.50)
Citrus	22210 (9.03)	Maharashtra (15.00), Andhra Pradesh (4.80)
Mango	21860 (8.89)	Andhra Pradesh (9.22), Maharashtra (5.00), Karnataka (2.30), Tamil Nadu (4.00), Gujarat (1.20)
Pomegranate	15250 (6.20)	Maharashtra (11.40), Karnataka (2.00)
Other crops	82236 (33.43)	
Total all crops	246006 (100.00)	

Note : Total will not tally as we have not included all the crops here.
Figures in brackets are percentage to total area.

Source : AFC (1998).

Studies based on research station data as well as farm level sample survey data have proved that drip method of irrigation has the capacity to increase water saving and productivity of crops significantly when compared to the crops cultivated under flood method of irrigation (INCID, 1994). However, drip method of irrigation is still essentially considered to be the scheme of the government. As of 1997-98, area under DMI other than government schemes (without subsidy) accounted for only about 18 percent of India's total drip irrigated area (see, Table 3.3). Studies need to be carried out as to why the individual farmers without subsidy are not willing to adopt drip method of irrigation despite substantial benefits from it.

Table 3.3 : Scheme-wise Area under Drip Method of Irrigation: 1997-98

Scheme	Area (ha)	Percent to Total
Centrally Sponsored Scheme	186644	64.64
Maharashtra State Scheme	58498	19.32
Oil palm and Sugarcane	884	0.29
Without Subsidy (private)	56780	18.75
Total	302806	100.00

Source : AFC (1998).

3.6 Development of Drip Irrigation in Maharashtra

As mentioned earlier, the growth of area under drip method of irrigation is exceptionally high in Maharashtra when compared to any other States in India. Therefore, an attempt is made in this section to present the trends and determinants of drip method of irrigation in Maharashtra. Area under DMI increased from a meagre 236 ha in 1986-87 to about 2,17, 447 ha in 2001-02, an increase of about 57 percent per annum. There are many reasons for the rapid development of drip irrigation in Maharashtra. First, state government is very keen in promoting drip irrigation on a large scale by providing subsidy, technical and extension services to the farmers. Maharashtra government has been providing subsidy since 1986-87 onwards through state schemes. Second, area under irrigation from both surface and groundwater is quite low and hence, many farmers have adopted drip method of irrigation to avoid water scarcity largely in divisions like Nashik, Pune, etc. Third, owing to continuous depletion of groundwater, farmers were not able to cultivate wide spaced and more lucrative crops like grapes, banana, pomegranate, orange, mango, etc. by using surface method of irrigation in many regions. As a result, farmers had to adopt drip irrigation as these crops are most suitable for drip method of irrigation. Importantly, the farmers who adopted drip irrigation initially for certain crops have realised the importance of drip irrigation in increasing the water saving and productivity of crops. This has further induced many farmers to adopt drip method of irrigation in some of the regions in Maharashtra.

Although drip irrigated area has been consistently increasing in Maharashtra, its development is not the same across different districts of the state. Development of drip irrigation is determined by factors like availability of surface water sources, groundwater development, cropping pattern, economic conditions of the farmers, rainfall, area under commercial and wide spaced crops, types of farmers, structure of farming (commercial and subsistence) availability of extension services and policy of the government. These determining factors widely vary across regions. In order to understand the region-wise development of drip irrigated area in Maharashtra, analysis has been done across the regions from 1986-87 to 1999-2000. Table 3.4 presents region-wise area under drip irrigation, its growth rate for different points of time. It is clear from the table that drip irrigated area in Maharashtra has consistently increased from about 237 ha in 1986-87 to 160281 ha in 1999-2000, an increase of about 65 percent per annum. Though area under DMI has increased appreciably in almost all the regions, growth rate of drip irrigated area is not uniform across the divisions. Between 1990-91 and 1999-2000, while the rate of growth of area under DMI is higher than the state's average in divisions like Nashik, Pune and Kolhapur, it is relatively lower than the state's average in other divisions. There are two main reasons for the rapid increase of drip irrigated area in divisions like Nashik, Pune and Kolhapur. First, crops that are most suitable for drip irrigation are being extensively cultivated in these regions by using groundwater. Second, these divisions are particularly facing water scarcity problem due to depletion of groundwater. Since both area under groundwater and wide spaced crops are less in divisions like Konkan and Nagpur, growth of drip-irrigated area is not impressive in these two divisions. Although there are variations in the development of drip area across the divisions, the overall development is very impressive in almost all the regions in 1999-2000 when compared to the position of 1990-91.

In order to understand the division-wise relative changes of drip irrigated area, we have computed division-wise share to total area

Table 3.4 : Division-wise Area under Drip Irrigation, its Proportion and Growth Rate: Central and State Schemes : 1999-2000

Division	Total Drip Area (ha) at the end of				Compound Growth Rate (%)				Districtwise Share of Area			
	1986-87	1990-91	1994-95	1999-00	A	B	C	D	1986-87	1990-91	1994-95	1999-00
Konkan Division	5	760	1865	5965	252.89	25.17	26.18	25.73	2.07	4.68	3.10	3.72
Nashik Division	26	3944	17227	56792	251.61	44.57	26.94	34.50	10.91	24.29	28.65	35.43
Pune Division	89	3302	13550	35289	146.53	42.33	21.10	30.11	37.80	20.34	22.54	22.02
Kolhapur Division	47	1403	5932	14814	133.75	43.39	20.09	29.94	19.87	8.64	9.86	9.24
Aurangabad Division	7	1714	5855	11054	291.47	35.94	13.55	23.01	3.09	10.56	9.74	6.90
Latur Division	21	1908	6713	14038	210.59	36.96	15.90	24.83	8.67	11.75	11.16	8.76
Amravati Division	21	2590	6556	16656	234.05	26.13	20.50	22.97	8.79	15.95	10.90	10.39
Nagpur Division	21	617	1955	5673	133.39	33.41	23.75	27.95	8.79	3.80	3.25	3.54
Total Maharashtra	237	16238	60130	160281	187.85	38.72	21.66	28.97	100.00	100.00	100.00	100.00

Notes : A - Growth rate 1990-91 over 1986-87;
B - Growth rate 1994-95 over 1990-91;
C - Growth rate 1999-2000 over 1994-95; D-Growth rate 1999-2000 over 1990-91.

Source : Government of Maharashtra, Commissionerate of Agriculture, Pune.

under drip irrigation for different points of time. The share of drip area has significantly changed during the period between 1990-91 to 1999-2000 in majority of the divisions. The share of Nashik division has consistently increased, while the share of Latur and Nagpur divisions has consistently declined during this period. For instance, the share of Nashik division has increased from about 24 percent in 1990-91 to about 35 percent in 1999-2000, while the same has declined from about 11 percent to about 8 percent in Latur division during the same period. Though the increase of area in absolute term is very significant in Pune division, its share has not increased very much between 1990-91 and 1999-2000. The shares of the other divisions in the total area under drip irrigation are not consistent. The main point emerges from here is that despite significant increase of area under DMI in almost all the districts in Maharashtra, the domination of Nashik and Pune divisions in the total area has been continuing.

Since DMI is relatively a new irrigation technology, both state and central governments have been operating separate schemes to promote drip method of irrigation. Maharashtra is one among the few states where both schemes are currently under operation. State scheme in the state has been in operation from 1986-87, while central scheme started functioning from 1990-91. Out of the total drip area of 60129 ha at the end of 1994-95, state scheme accounted for about 75 percent of the total area.[14] State scheme occupies more area in all the districts when compared to Central schemes.[15] It is also observed wherever the area coverage under state scheme is higher, there area under central scheme is also higher. In other words, there is a positive association between area under State and Central scheme in all the districts. For example, Nashik division accounted for about 26 percent of area in the total of State scheme, while the same division accounted for about 35 percent in the total area of Central scheme. Similarly, Pune division accounted for about 21 percent in Central scheme and 22 percent in State scheme. There are two reasons why State scheme accounts for higher share in all the districts. First, State scheme was started during 1986-87, whereas the central scheme was implemented only in 1990-91. Second, State scheme provides subsidy even for sugarcane, whereas

14. Area under DMI separately for State and Central Schemes is not readily available for our use after 1994-95. However, to understand the magnitude of these two schemes, we have analysed it using the available data.

15. State scheme area refers to the area under drip irrigation by the farmers benefited from state scheme, whereas central scheme refers to the area under drip irrigation benefited from central scheme.

central scheme does not provide subsidy for sugarcane. One of the main differences that we have noted between Central and State scheme is that the complete demonstration area of drip irrigation comes under the Central scheme.

Attempt is also made to find out the number of farmers who have adopted drip irrigation and the amount of money distributed in the form of subsidy together for State and Central schemes for each division (see, Table 3.5). Altogether up to March 2000, a total of

Table 3.5 : Division-wise Area under Drip Irrigation and Total Subsidy Distributed Upto 1999-2000

Division	Total Area (ha)	Total Subsidy (Rs. Lakh)	No. of Farmers	Subsidy/ ha.	Average Area/ Farmer
Konkan Division	5965.48	640.28	3358	10733	1.78
Nashik Division	56792.25	9470.92	64877	16676	0.88
Pune Division	35289.31	5437.63	41104	15409	0.86
Kolhapur Division	14813.82	2570.56	23436	17352	0.63
Aurangabad Division	11053.6	1498.45	10208	13556	1.08
Latur Division	14037.78	2270.47	12861	16174	1.09
Amravati Division	16656.05	2273.93	13658	13652	1.22
Nagpur Division	5673	775.06	4294	13662	1.32
Total Maharashtra	160281.29	24937.3	173796	15558	0.92

Source : Government of Maharashtra, Commissionerate of Agriculture, Pune.

173796 drip sets have been installed, for which an amount of Rs. 24937.3 lakh have been distributed as subsidy through Central and State schemes. There is a positive relationship between area under drip method of irrigation and the number of sets installed across districts. However, there is a wide variation in the average area under DMI per farmer across the divisions. Though the total area under DMI is very high in divisions like Nashik and Pune, the average area per farmer is very less (only around 0.86 ha) in these two divisions. On the other hand, the average area per set is very high in divisions like Konkan and Nagpur, despite a very low level of area under DMI. This is possibly due to difference in crop pattern that are brought under DMI. Data also shows that in both Konkan and Amravati divisions, farmers have used DMI mainly for mango and citrus group of crops. Since mango and citrus (mainly orange) gardens are relatively larger than others, the average area per farmer is larger in these divisions when compared to other divisions. Unlike this, the crop composition of both Pune and Nashik division is mixed, where considerable amount of area of narrow spaced crops (vegetables, etc) are also cultivated under DMI. Therefore, the average area per farmer is relatively less in these divisions. Owing to considerable variation in crop composition across the divisions, the average per hectare subsidy also varies greatly from Rs.10733/ha in Konkan division to Rs.17352/ha in Kolhapur division.

3.7 Crop-wise Area under Drip Irrigation in Maharashtra

Like general cropping pattern, crops cultivated under DMI also vary across the divisions in Maharashtra. More than 26 crops are being cultivated using drip irrigation in the state as of March 2000. The important crops are banana, grapes, sugarcane, citrus group of crops and pomegranate. These five crops together have accounted for about 120335 ha which accounts for about 75 percent of the total area (160281 ha) under drip irrigation in Maharashtra. The crop-wise share of total area under DMI presented in Table 3.6 clearly shows that distribution of crop varies widely across divisions. In the total area under drip irrigation in Maharashtra, banana accounts for more than one fifth of the area (22.38 percent) followed by grapes (18.15 percent), sugarcane (12.68 percent), citrus group of crops (11.59 percent) and pomegranate (10.27 percent). However, this is not the same for all the districts/divisions. Crops like mango, coconut and chiku accounted for over 66 percent of Konkan division's total area under drip irrigation, while crops like banana (47.48 percent) and grapes (29.73 percent) accounted for more than three fourth of the total drip irrigated area in Nashik division. Sugarcane (23.73 percent), pomegranate (22.79 percent) and grapes (14.27 percent) together have accounted for over 60 percent of drip irrigated area of Pune division. This clearly shows that crop composition varies with the existing crop pattern and the ecological conditions of each division/district.

Similar to crop-wise distribution, division-wise share of drip irrigated area for each crop is computed to understand how a particular crop concentrates across the divisions. Table 3.7 shows division-wise share of area of each crop cultivated using DMI. While crops like banana and grapes are mainly concentrated in Nashik division, sugarcane is concentrated in Pune and Kolhapur division - these two divisions together have accounted for about 60 percent of total sugarcane area. Citrus group of crops are concentrated in Amravati division (43.42 percent), whereas Nashik and Pune divisions together have accounted for about 81 percent of the total area of

Table 3.6 : Crop-wise Share of Drip Area in Maharashtra upto 1999-2000

Division	Banana	Grape	S'cane	CGC	PGN	Mango	Ber	VEG	Chicku	Papaya	Guava	C.nut	Others	Total
Konkan Division	6.50	0.00	0.00	0.58	0.03	34.17	0.00	9.27	15.47	1.11	0.20	16.55	16.12	100.00
Nashik Division	47.48	29.73	3.90	1.55	9.37	0.50	0.33	0.70	0.28	0.39	0.31	0.01	5.43	100.00
Pune Division	4.19	14.27	23.73	4.73	22.79	3.11	6.98	5.27	3.43	0.84	2.14	0.31	8.21	100.00
Kolhapur Division	2.04	33.77	26.79	1.43	11.38	5.88	2.26	3.10	1.93	0.83	0.71	1.31	8.57	100.00
Aurangabad Division	10.56	5.07	14.21	30.34	4.22	8.24	2.56	2.07	3.59	2.05	1.63	0.41	15.05	100.00
Latur Division	22.80	9.62	22.22	12.12	4.16	5.53	2.72	2.14	2.27	3.73	1.17	1.04	10.51	100.00
Amravati Division	11.56	1.57	4.46	48.43	2.10	2.90	1.63	2.60	1.50	2.45	1.47	0.05	19.26	100.00
Nagpur Division	7.86	0.02	5.89	46.92	0.24	10.72	1.22	2.54	1.40	3.74	1.23	0.15	18.06	100.00
Total Maharashtra	22.38	18.15	12.68	11.59	10.27	4.41	2.49	2.73	2.26	1.30	1.06	0.94	9.72	100.00

Notes : CGC-Citrus Group Crops; PGN-Pomegranate; VEG-Vegetables; C.nut-Coconut
Source : Government of Maharashtra, Commissionerate of Agriculture, Pune.

Table 3.7 : Division-wise share of Drip Area in Maharashtra Up to 1999-2000

Division	Banana	Grape	S'cane	CGC	PGN	Mango	Ber	VEG	Chicku	Papaya	Guava	C.nut	Others
Konkan Division	1.08	0.00	0.00	0.19	0.01	28.82	0.00	12.63	25.47	3.17	0.71	65.57	6.17
Nashik Division	75.17	58.03	10.89	4.73	32.32	4.04	4.72	9.12	4.40	10.79	10.30	0.56	19.80
Pune Division	4.12	17.30	41.20	8.99	48.84	15.54	61.72	42.48	33.44	14.23	44.20	7.20	18.59
Kolhapur Division	0.84	17.19	19.53	1.14	10.24	12.32	8.37	10.50	7.88	5.94	6.17	12.85	8.14
Aurangabad Divi.	3.25	1.93	7.73	18.05	2.83	12.88	7.09	5.22	10.94	10.90	10.56	3.03	10.68
Latur Division	8.92	4.64	15.35	9.15	3.54	10.98	9.55	6.85	8.78	25.15	9.61	9.68	9.46
Amravati Division	5.37	0.90	3.66	43.42	2.13	6.83	6.81	9.91	6.90	19.63	14.36	0.53	20.58
Nagpur Division	1.24	0.00	1.64	14.33	0.08	8.60	1.74	3.29	2.20	10.19	4.10	0.57	6.57
Total Maharashtra	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Notes and Source: Same as in Table 3.6.

pomegranate. About 65 percent of coconut area is concentrated only in Konkan division.

This wide variation in distribution of crops' area indicates the fact that the adoption of DMI across the districts/divisions varies depending upon the climatic and other ecological factors. Although there is a wide variation in distribution of crops across the divisions, Pune division occupies an important place in almost all the major crops that are cultivated under DMI in Maharashtra. It seems that Pune's climatic factors and cropping pattern are most suitable for the adoption of drip irrigation. In the following section, an attempt is made to find out the factors which determine the adoption of drip method of irrigation in Maharashtra.

3.8 Factors Determining Development of Drip Area

It is understood from the earlier section that the development of drip irrigated area is not uniform across the divisions/districts in Maharashtra. Area under drip irrigation has increased quite impressively in some divisions/districts, while in other districts it is quite low. In order to understand the factors which influence the development of drip irrigation, we have made detailed analysis across the districts by taking into account the factors like rainfall, area under groundwater, area under surface irrigation, irrigation intensity, cropping intensity, area under non-foodgrain crops and fertilisers use. We understand from some of the earlier studies (e.g., Shrestha and Gopalakrishnan, 1993; Narayanamoorthy, 1996a) that the above-mentioned factors either directly or indirectly influence the diffusion of drip method of irrigation.

Let us understand theoretically how these factors can influence the development of drip irrigation before going to study the empirical relationship of these factors. As drip method of irrigation is mainly used for water saving or to avoid water scarcity, farmers hesitate to adopt drip irrigation in the area where rainfall is in abundance. Therefore, development of drip irrigation is expected to be low in the regions where good rainfall is received. Availability of groundwater is one of the important factors for the development of drip irrigation since DMI is most suitable for groundwater based irrigation. Adoption of drip irrigation is expected to be large in the areas where farmers face groundwater scarcity or depletion of groundwater, while DMI adoption is expected to be slow in the area with good groundwater potential. Crop pattern of a particular district/region also influences the adoption of drip irrigation. The existing drip irrigation technology is not suitable for foodgrain crops like paddy, wheat, etc.

Hence, the development of drip irrigation will be slow in the regions where area under foodgrain crop is large. The rate of adoption of drip irrigation is expected to be more in the area where wide spaced crops like grapes, banana, mango, pomegranate, etc., are being cultivated extensively using surface method of irrigation. Availability of surface water sources like canal and tank can also influence the adoption of drip irrigation to some extent. If farmers come to know that the surface irrigation is assured and also available for future use, farmers may not be willing to adopt drip method of irrigation as it is considered to be a capital-intensive technology.

In order to understand the factors, which influence the development of drip irrigation, we have attempted two kinds of analyses. They are (1) simple percentage analysis (comparing share of each independent variable with drip irrigated area of different districts and divisions), and (2) correlation and regression analysis. We are aware very well that since the adoption of drip irrigation is still in the take-off stage in the state, the analysis attempted here would not give any strong results. However, our endeavour here is to understand the sign of development through this analysis.

The factors, which are expected to influence the development of drip irrigation, are presented in Table 3.8. It is clear from the table that there is a negative association between rainfall and drip irrigated area. The level of rainfall in divisions like Konkan, Nagpur and Kolhapur is good and therefore, the development of drip irrigated area is very less in these divisions. This is obvious that when rainfall of a region is good, farmers need not go for capital-intensive methods like drip irrigation as indicated already. Second important result of the analysis is the positive relationship between groundwater area and drip-irrigated area. Percentage of groundwater area to total irrigated area is much higher in divisions like Nashik, Pune and Latur when compared to state's average. As result of higher percentage of groundwater, the share of area under drip irrigation of these divisions is quite high as compared to other divisions. Another important reason for using drip irrigation extensively in divisions like Pune and Nashik is depletion of groundwater. Owing to drastic depletion of groundwater, many farmers have faced water problem in divisions like Pune and Nashik especially to cultivate high remunerative crops under surface method of irrigation. This has forced many farmers to adopt drip method of irrigation for crops like grapes and banana extensively. It is also observed that area under drip irrigation is higher where the consumption of fertiliser per ha is higher. This implies that the adoption of drip irrigation is higher in the agriculturally developed regions.

Table 3.8 : Districtwise Factors Determining Drip Irrigated Area in Maharashtra : 1998-99

Sr. No.	District	% of Drip Area	Rainfall (mm)	Fertiliser (ha)	GIA/ GCA (percent)	NSIA/ NIA (percent)	GWA/ NIA (percent)	II (%)	CI (%)	NFGA/ GCA (percent)
1	2	3	4	5	6	7	8	9	10	11
1.	Thane	1.78	2696	65.1	5.60	32.28	67.72	114.96	106.54	26.29
2.	Raigad	0.50	3284	80.8	5.14	84.38	15.63	116.67	115.49	46.58
3.	Ratnagiri	0.85	3761	31	1.41	10.34	89.66	124.14	104.16	54.50
4.	Sindhu-durg	0.58	4180	41.2	19.48	93.93	6.07	110.36	113.12	42.56
	Konkan Division	**3.72**	**3480**	**54.5**	**6.76**	**72.93**	**27.07**	**113.35**	**109.01**	**36.56**
5.	Nashik	14.53	1128	103.9	21.89	11.23	88.77	122.23	109.88	20.44
6.	Dhule	2.53	969	84.1	12.81	10.85	89.15	135.40	111.35	35.18
7.	Nandurbar	0.23	(New district and hence data are not available)							
8.	Jalgaon	18.14	1065	108.4	14.35	2.39	97.61	121.16	153.91	59.68
	Nashik Division	**35.43**	**1054**	**98.8**	**16.31**	**7.79**	**92.21**	**124.33**	**125.47**	**40.89**
9.	Ahmed-nagar	6.67	820	84.1	23.19	27.55	72.45	117.62	126.63	29.32
10.	Pune	5.53	1138	78	23.73	41.87	58.13	118.65	119.90	32.85
11.	Solapur	9.82	1150	79.6	21.36	26.03	73.97	120.36	108.27	34.15
	Pune Division	**22.02**	**1036**	**80.5**	**22.81**	**31.79**	**68.21**	**118.72**	**118.52**	**31.87**
12.	Satara	2.41	1367	90.4	27.32	47.69	52.31	124.41	119.47	31.45
13.	Sangli	5.37	771	114.9	18.79	32.83	67.17	121.60	114.92	22.90
14.	Kolhapur	1.47	1862	149.6	15.80	67.67	32.33	106.33	167.69	70.51
	Kolhapur Division	**9.24**	**1333**	**118.3**	**20.60**	**49.21**	**50.79**	**118.32**	**130.63**	**42.01**
15.	Auranga-bad	3.77	896	70.5	18.04	16.63	83.37	112.35	145.01	43.67
16.	Jalna	1.86	1152	64	16.03	34.44	65.56	126.84	122.63	38.19
17.	Beed	1.27	1231	51.8	19.94	28.36	71.64	117.18	119.57	29.74
	Auranga bad Divi.	**6.90**	**1093**	**62.1**	**18.14**	**27.52**	**72.48**	**117.45**	**129.03**	**37.34**
18.	Latur	2.45	1220	75.7	7.92	10.02	89.98	126.06	133.79	34.99
19.	Usma-nabad	1.22	1160	31.8	16.81	20.97	79.03	117.20	142.19	24.57
20.	Nanded	2.30	1023	128.6	8.89	33.74	66.26	125.95	115.28	44.53
21.	Parbhani	2.79	1321	46.4	8.11	60.62	39.38	173.10	159.56	47.29

1	2	3	4	5	6	7	8	9	10	11
	Latur Division	8.76	1181	70.6	10.00	31.02	68.98	133.45	138.60	39.61
22.	Buldhana	2.11	1104	69.8	5.68	3.47	96.53	127.73	121.69	45.43
23.	Akola	1.70	1034	65	2.87	16.52	83.48	137.05	130.71	49.70
24.	Washim	0.10	(New district and hence data are not available)							
25.	Amravati	4.57	974	43.9	6.09	4.96	95.04	134.48	136.20	65.22
26.	Yavatmal	1.92	844	56.7	4.54	26.64	73.36	153.98	115.33	59.45
	Amravati Division	**10.39**	**951**	**58.8**	**4.74**	**11.09**	**88.91**	**137.20**	**125.83**	**55.28**
27.	Wardha	1.26	980	77.6	7.73	10.14	89.86	144.44	105.59	61.89
28.	Nagpur	1.64	1036	64.4	15.93	44.33	55.67	138.88	108.07	54.93
29.	Bhandara	0.42	1347	80.3	50.24	88.27	11.73	115.48	118.01	4.96
30.	Chand-rapur	0.18	1242	52.3	19.60	90.58	9.42	111.98	121.43	36.96
31.	Gadchiroli	0.04	1413	77.3	26.18	95.25	4.75	109.07	107.89	1.97
	Nagpur Division	**3.54**	**1204**	**70.3**	**23.07**	**78.55**	**21.45**	**119.20**	**112.66**	**36.96**
	Total Mahara-shtra	**100.00**		**76.5**	**15.24**	**38.57**	**61.43**	**121.59**	**124.94**	**40.82**

Notes: GWA/NIA-Percentage of Groundwater Area to Net Irrigated Area; SIA/NIA-Percentage of Surface Irrigated Area to Net Irrigated Area;GIA/GCA-Percentage of Gross Irrigated Area to Gross Cropped Area; II-Irrigation Intensity (in percent); CI-Cropping Intensity (in percent); NFGA/GCA - Percentage of Non-Foodgrains Area to GCA; Except irrigation, all other data are related to 1998-99; Irrigated area is related to 1994-95.

Source : Computed from Government of Maharashtra (2000).

In order to understand the nature of statistical relationship with area under drip irrigation across the districts, correlations are computed for the above-mentioned variables (see, Table 3.9). As we noted earlier from simple percentage analysis, the association between area under groundwater and area under drip irrigation is positive and significant. This means that drip area is more wherever the percentage of groundwater area to net irrigated area (GWA/NIA) is higher. Similar to groundwater, consumption of fertilisers per ha is also positively and significantly associated with area under drip irrigation, implying that the adoption of DMI is higher in the agriculturally advanced districts of Maharashtra. As expected, the association is negative (not significant) between rainfall and drip irrigated area. Other than these three variables, the correlation value is very weak with other variables. Against our expectation the value of correlation with percentage of non-foodgrains area to gross cropped area (NFCA/GCA) turned out to be very weak.

Table 3.9 : Results of Linear Regression: Factors Determining Area under Drip Irrigation

Sr. No.	Variable	Dependent Variable: Area under Drip Irrigation				Correlation Value
		Constant	Slope	R^2	Adjusted R^2	
1.	Rainfall (mm)	8756.51 (3.67)[a]	-2.23 (-1.58)[d]	0.09	0.05	-0.29
2.	Fertiliser Consumption (ha)	-1259.12 (-0.36)	90.56 (2.07)[b]	0.14	0.11	0.37[b]
3.	Percentage of GWA to NIA	-767.21 (-0.28)	99.67 (2.53)[a]	0.19	0.16	0.44[a]
4.	Percentage of SIA to NIA	9199.71 (4.97)[a]	-99.67 (-2.53)[a]	0.19	0.16	-0.44[a]
5.	Percentage of GIA to GCA	4539.99 (1.94)[c]	63.06 (0.49)	0.01	-0.03	0.09
6.	Irrigation Intensity (GIA/NIA) (in %)	7368.70 (0.65)	-14.88 (-0.17)	0.001	-0.04	-0.03
7.	Cropping Intensity (GCA/NSA) (in %)	-3471.50 (-0.37)	72.86 (0.96)	0.03	-0.003	0.18
8.	Percentage of Area under Non-Foodgrain Crops (NFGA/GCA)	4972.43 (1.49)[d]	13.52 (0.17)	0.001	-0.04	0.03

Notes : a, b, c and d are significant level at 1, 5, 10 and 20 percent respectively. Figures in brackets are 't' values.

Source : Computed using data compiled from Government of Maharashtra (2000).

With a view to understand the strength of each variable in influencing the area under drip method of irrigation, we have also computed simple linear regressions for the variables that are considered to be important in influencing the adoption of drip irrigation. Among the eight linear regression models, the co-efficients of three variables, namely, rainfall, percentage of groundwater area to net irrigated area (GWA/NIA) and consumption of fertiliser per ha point to a significant value (see, Table 3.9). The negative co-efficients of rainfall implies that one unit increase in rainfall would reduce about 1.35 unit of drip irrigated area. This is not surprising result because when rainfall of a particular district or region is higher, farmers hesitate to adopt drip method of irrigation for crop cultivation. The coefficient of percentage of groundwater area (GWA/NIA) implies that one unit increase in area under groundwater irrigation will increase nearly 100 ha of area under drip irrigation. Similarly, the coefficient of fertilisers consumption implies that an unit increase of fertilisers consumption would increase over 90 unit of drip area in Maharashtra. Altogether, it is clear from the statistical analysis that the percentage of groundwater area is the important variable which influence the growth of drip irrigated area to a greater extent in Maharashtra.

On the whole, it is clear from the above that area under drip irrigation is substantially higher in Maharashtra when compared to any other state in India. As per the data of 2000-01 it ranks the first place in India, occupying nearly 53 percent of India's total drip irrigated area. While the area under DMI increased from 1500 ha in 1985-86 to about 5 lakh hectares in March 2003 at the all India level, it has consistently increased from about 236 ha in 1986-87 to about 160.28 thousand hectares ha in 2000-01 in Maharashtra. Districts that come under the divisions of Nashik and Pune continue to dominate in the total area under drip irrigation since the beginning of the schemes. The main crops that are cultivated under DMI in the State are banana, grapes, sugarcane, citrus group of crops and pomegranate. The district-wise analysis seems to indicate that the severe water scarcity especially in groundwater source along with favourable cropping pattern and policy environment (promotional schemes) could be the some of the main factors responsible for the significant growth in drip irrigated area in Maharashtra.

Chapter 4

Water and Electricity Saving

4.1 Introduction

Considering the fast decline of potential water resources and the constraints on energy use, it has become essential to adopt resource-conserving technologies. This would also help in sustaining the process of agricultural development in the long run. It has been proved by some earlier studies that drip method of irrigation helps to save water and improves water use efficiency (INCID, 1994). While reducing water consumption, it also reduces substantial amount of electricity required for irrigation purpose, by reducing working hours of irrigation pumpsets (Narayanamoorthy, 1996a). As mentioned earlier, quite a few studies have analysed the water use pattern under DMI. However, not many studies have attempted to estimate the saving in electricity due to DMI, either using farm level data or experimental research data. Our attempt in this chapter is to analyse the pattern of water use, water conservation and electricity saving due to drip method of irrigation. Both the experimental and field level data have been used to analyse the impact of DMI on water saving and electricity saving. This chapter has been broadly divided into three sections. While the first section deals with the water use pattern using experimental data, the second section analyses the impact of DMI on water saving using farm level data in the context of three crops namely sugarcane, grapes and banana. The third section analyses the impact of DMI on electricity use in the context of three crops. This is attempted keeping in view the difficulties in measurement. It is not an easy task to undertake an attempt to estimate resource conservation in field conditions where the measurements are not only inadequate but at time erroneous.

4.2 Water Saving - Experimental Data

As mentioned earlier, DMI not only helps to reduce the consumption of water (by reducing evaporation and distribution losses) but also increases the productivity of crops. Considering the importance of drip method of irrigation in the sustainable use of irrigation water, efforts are being made to propagate the adoption of DMI from 1970 onwards in India (INCID, 1994). Special subsidy schemes were introduced during the eighties by the central and state governments for promoting this technology since DMI is considered to be a relatively capital-intensive technology. Though studies using field level data are rarely available focusing water use efficiency and water saving of DMI, many research stations situated in different parts of the country have evaluated the water saving capacity of DMI for different crops. We have presented the water requirements, saving of water and water use efficiency under DMI and FMI for different crops in Table 4.1 based on the data from experimental stations.

Table 4.1 : Water Saving through Drip Method of Irrigation - Experimental Results

Crop's Name	Water Consumption (mm/ha)		Water Saving over FMI (%)	Water Use Efficiency$	
	FMI	DMI		FMI	DMI
Vegetables:					
Ash gourd	840	740	12	77.49	61.51
Bottle gourd	840	740	12	22.09	13.26
Brinjal	900	420	53	32.14	13.13
Beet root	857	177	79	187.53	36.20
Sweet potato	631	252	61	148.82	42.78
Potato	200	200	Nil	8.49	5.81
Lady's finger	535	86	84	53.50	7.60
Onion	602	451	25	64.73	36.97
Radish	464	108	77	441.90	90.76
Tomato	498	107	79	80.58	12.06
Chillies	1097	417	62	259.34	68.47
Ridge gourd	420	172	59	24.52	8.60
Cabbage	660	267	60	33.71	13.35
Cauliflower	389	255	34	46.67	22.00
Fruit Crops:					
Papaya	2285	734	68	175.77	31.91
Banana	1760	970	45	30.61	11.09
Grapes	532	278	48	20.15	8.55
Lemon	42	8	81	22.34	3.17
Watermelon	800	800	Nil	27.15	9.07
Mosambi	1660	640	61	16.60	4.27
Pomegranate	1440	785	45	26.18	7.20
Other Crops:					
Sugarcane	2150	940	65	16.79	5.53
Cotton	856	302	60	329.23	92.64
Coconut	—	—	60	—	—
Groundnut	500	300	40	292.40	105.63

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

For the purpose of analysis, we have divided the crops into three groups as vegetable crops, fruit crops and other commercial crops. This is done specifically to understand how the saving of water varies across different crop groups. The water saving capacity of DMI is expected to be different for different crops as the consumption and the requirement of water varies from crop to crop. As expected, the water saving for vegetable crops varies from 12 percent to 84 percent per hectare over the conventional method of irrigation. Similarly, water saving varies from 45 percent to 81 percent per hectare in fruit crops. In crops like cotton, coconut and groundnut, water saving varies from 40 percent to 60 percent per hectare. Importantly, water saving in sugarcane, which is one of the water-intensive crops, is over 65 percent per hectare when compared to conventional method of irrigation.

Table 4.2 : Results of Studies on Micro-irrigation by PFDCs

Crop's Name	Yield (Q/ha)		Irrigation (cm)		Water Use Efficiency (q/ha/cm)		Advantage of DMI (%)	
	SMI	DMI	SMI	DMI	SMI	DMI	SMI	DMI
Beet	5.70	8.90	86.00	18.00	0.07	0.50	79.10	56.10
Bitter Gourd	32.00	43.00	76.00	33.00	0.42	1.30	56.60	34.40
Brinjal	91.00	148.00	168.00	64.00	0.55	2.30	61.90	62.60
Broccoli	140.00	195.00	70.00	60.00	2.00	3.25	14.30	39.30
Cauliflower	171.00	274.00	27.00	18.00	6.30	15.20	33.30	60.20
Chilly	42.30	60.90	109.00	41.70	0.39	1.50	61.70	44.00
Cucumber	155.00	225.00	54.00	24.00	2.90	9.40	55.60	45.20
Lady's Finger	100.00	113.10	53.50	8.60	1.87	13.20	84.00	13.10
Onion	284.00	342.00	52.00	26.00	5.50	13.20	50.00	20.40
Potato	172.00	291.00	60.00	27.50	2.90	10.60	54.20	69.20
Radish	10.50	11.90	46.00	11.00	0.23	1.10	76.10	13.30
Sweet Potato	42.40	58.90	63.00	25.00	0.67	2.40	60.30	38.90
Tomato	61.80	88.70	49.80	10.70	1.24	8.28	78.50	43.50
Banana	575.00	875.00	176.00	97.00	3.27	9.00	45.00	52.20
Grapes	264.00	325.00	53.00	28.00	5.00	11.60	47.20	23.10
Papaya	130.00	230.00	228.00	73.00	0.60	3.20	67.90	76.90
Pomegranate	34.00	67.00	21.00	16.00	1.62	4.20	23.80	97.00
Water Melon	82.10	504.00	72.00	25.00	5.90	20.20	65.30	513.90

Source : GOI (2004), *Report of Task Force on Micro Irrigation* (Chairman: Chandrababu Naidu), Ministry of Agriculture, Government of India, January.

Similar to the results available from INCID (1994) report, various experimental studies carried out by the Precision Farming Development Centre (PDCs) also clearly demonstrate that water saving due to DMI is substantial over the method of surface irrigation in different crops (see, Table 4.2). There are three main reasons for enormous water saving under drip method of irrigation. First, since water is supplied through a network of pipes, the evaporation and distribution losses of water are very minimum or completely absent under DMI. Second, unlike FMI, water is supplied under DMI at a required time and required level and thus, over-irrigation is totally avoided. Third, under the conventional method of irrigation, water is supplied for the whole cropland, whereas DMI irrigates only the plants. Though the results of the experimental data discussed above clearly suggest that water saving due to DMI is substantial, one cannot completely rely on these results because the environmental conditions that are prevailing under experimental stations are totally different from the farmers' field. Therefore, in the following section, we discuss the water saving including its efficiency under DMI using farm level data in the context of three crops namely sugarcane, banana and grapes.

4.3.0 Pattern of Water Use - Farm Level Data

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. Government control on water use is negligible in the groundwater-irrigated condition. 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).

Since water is supplied through a pipe network in drip method of irrigation mainly using groundwater, the water supply can be controlled easily. Therefore, pattern of water use under drip method irrigation may not be the same with the farmers who use flood method of irrigation. Here, we have tried to analyse the pattern of water use between the adopters of drip irrigation and the non-adopters. 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 are reported in Table 4.3. In all the three crops, the number of irrigations used per hectare are higher for the drip adopters. 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. In order to maintain the moisture level, farmers with DMI use water at required frequency 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.

Table 4.3 : 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).

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, in sugarcane, farmers 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. In the case of grapes, farmers with DMI have used almost 12 less hours for each turn of irrigation as compared to the non-drip counterpart. This is true in banana crop as well. Since drip method of irrigation supplies water only at the root zone of the crop, time required per irrigation is much less. But in the case of surface method, farmers have to spend more time for each turn of irrigation, 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, in spite of higher amount of water supply for each turn of irrigation under flood method of irrigation, farmers could not avoid moisture stress faced by the crops. 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.

4.3.1 Quantity of Water Consumption

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 (WEMs), 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 per unit of land 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 centimeter (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.

Table 4.4 presents per hectare consumption of water in terms of HP hours for drip and non-drip adopters for all three crops. It is clear from the table 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 (see, Figure 4.1). 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 it is 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 show that drip technology helps saving relatively more water in water-intensive crops like banana.

Figure 4.1: Water Saving due to Drip Method of Irrigation

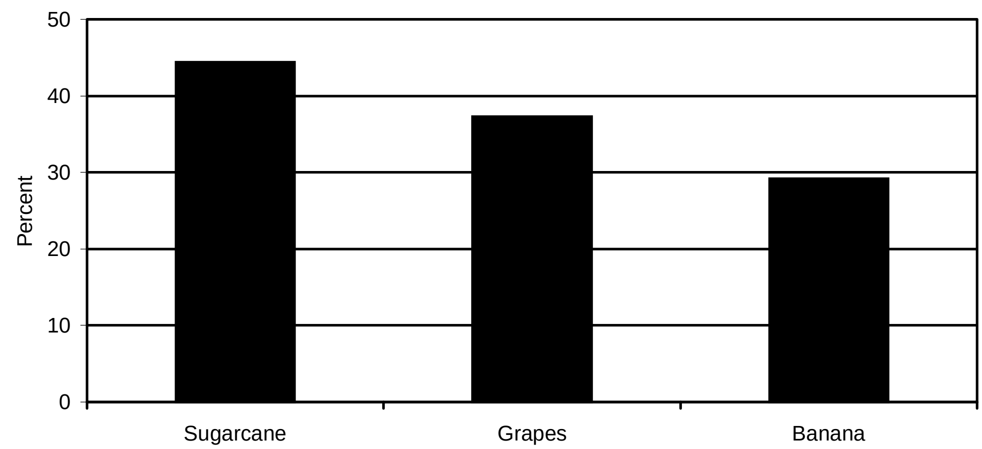


Table 4.4: Water Consumption by Drip and Non-Drip Irrigated Crops

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).

It is also possible to increase the area under irrigation from the saving of water achieved due to the adoption of drip method of 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.

4.3.2 Water Use Efficiency

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. In order to study the water use efficiency under the two method of irrigation, we have calculated water consumption required producing one unit of output under drip and non-drip irrigated condition. In order to arrive at per quintal water requirement, water consumption per hectare has been divided by the per hectare yield of crops.

Table 4.5: 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 4.5. 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. The analysis shows that sugarcane cultivated under drip method of irrigation consumes only 1.28 HP hours of water to produce one quintal of output when compared to 2.83 HP hours of water for producing the same quantity of output under non-drip irrigated condition, i.e., to produce one quintal of sugarcane under non-drip irrigated condition about 1.55 HP hours of additional water is consumed. 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. The fact 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 saving are highly interrelated under DMI and therefore, an analysis on electricity use under drip method is presented in the following section.

4.4 Electricity Saving under Drip Method of Irrigation

It is a well-known fact that due to rapid energisation of pumpsets and widespread cultivation water intensive crops, consumption of electricity by agricultural sector has increased many fold since independence.[16] 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

16. For more details regarding the trends and determinants of electricity consumption in Indian agriculture see, Narayanamoorthy (1999b).

various reasons. One among the options available for increasing the efficiency of electricity use in agriculture is drip method of irrigation. Preliminary level studies related to drip method of irrigation have shown that this micro-irrigation technology is not only useful for reducing the consumption of water but also useful in energy saving. 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 in 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. Further, 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.[17] 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 4.6 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.

17. For more details in this regard, see Shah (1993), *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy*, Oxford University Press, Delhi, pp. 92-112.

Table 4. 6 : Estimates of Electricity Consumption by Drip and Non-Drip Irrigated Crops

District	Electricity Consumption (Kwh/ha)		Electricity Saving over FMI		
DMI	FMI	In Percent	In quantity	In money (Kwh)	value (Rs)*
Sugarcane	1325.25	2384.99	44.43	1059.74	3454.75
Grapes	2482.77	3958.78	59.45	1476.01	4811.80
Banana	5913.53	8347.75	41.16	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).

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. In accordance with this, 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. 4811and Rs. 7934 per hectare 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.

Table 4.7 : 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).

In order to explain electricity saving in a simplest way 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 4.7. 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.

On the whole, it is clear from both the experimental and field level data that water saving due to drip method of irrigation is substantial in different crops. Because of substantial amount water saving, electrical energy required for irrigation purpose is also found to be very less in drip-irrigated crops as compared to the crops cultivated using surface/conventional method of irrigation. The other two important advantages of drip method of irrigation are gains in cost of cultivation and productivity of crops. We present an analysis about the impact of DMI on these two parameters in the following chapter.

Chapter 5

Cost of Cultivation and Productivity Gains

5.1 Introduction

Apart from reducing water consumption and electricity consumption, drip method of irrigation also helps to reduce the cost of cultivation and improve productivity of crops as compared to the same crops cultivated under flood method of irrigation. Therefore, in this chapter, we discuss about the impact of DMI on cost of cultivation and productivity of crops using both the experimental and field level data. First, we discuss about the productivity enhancement in different crops due to DMI using experimental data and then we study the impact of DMI on cost of cultivation and productivity of crops using field level data pertaining to three crops namely sugarcane, grapes and banana.

5.2 Productivity of Crops - Experimental Data

As mentioned earlier, quite a few studies have attempted to study the impact of drip method of irrigation on productivity of crops, mainly using experimental data. INCID (1994) report presents the results of various crops carried out at different locations in the country, which are presented in Table 5.1. The results of the experimental station data show that the productivity of different crops is significantly higher under DMI when compared to FMI. For instance, productivity increase due to drip method of irrigation is noticed over 40 percent in vegetable crops such as bottle gourd, potato, onion, tomato and chillies. Similarly, productivity increase due to DMI is noticed over 70 percent in many fruit crops. Productivity difference is also found to be over 33 percent in sugarcane cultivated under DMI over the same crop cultivated under FMI. Specific experiments carried out at Punjabrao Krishi Vidyapeeth, Akola, (Maharashtra State) on vegetable crops such as cauliflower, tomato and brinjal also suggest that productivity enhancement due to DMI is substantial (see, Table 5.2). Similar kinds of results have also been noted at different experimental stations located in different states.[18]

18. The results of experiments carried out in different locations and in various crops are available in INCID (1994).

Table 5.1 : Productivity Gains through Drip Method of Irrigation - Experimental Results

Crop's Name	Yield (tonne/ha)		Yield Increase over FMI (%)
	FMI	DMI	
Vegetables :			
Ash gourd	10.84	12.03	12
Bottle gourd	38.01	55.79	47
Brinjal	28.00	32.00	14
Beet root	4.57	4.89	7
Sweet potato	4.24	5.89	40
Potato	23.57	34.42	46
Lady's finger	10.00	11.31	13
Onion	9.30	12.20	31
Radish	1.05	1.19	13
Tomato	6.18	8.87	43
Chillies	4.23	6.09	44
Ridge gourd	17.13	20.00	17
Cabbage	19.58	20.00	2
Cauliflower	8.33	11.59	39
Fruit Crops :			
Papaya	13.00	23.00	77
Banana	57.50	87.50	52
Grapes	26.40	32.50	23
Lemon	1.88	2.52	35
Watermelon	29.47	88.23	179
Mosambi*	100.00	150.00	50
Pomegranate*	55.00	109.00	98
Other Crops :			
Sugarcane	128.00	170.00	33
Cotton	2.60	3.26	25
Coconut	—	—	12
Groundnut	1.71	2.84	66

Notes : * - yield in 1000 numbers.
Sources : INCID (1994) and NCPA (1990).

A number of studies have also been carried out in the context of sugarcane using experimental data, which are worth discussing here. A study conducted at the factory farm of Shakthi Sugars at Baramba in Orissa showed that yield of sugarcane was 31.04 tonnes per acre under drip irrigated plot against the yield of 26.10 tonnes per acre under flow method of irrigation. Though the study has not given any details about water use efficiency under drip irrigation, single cane weight, cane girth, cane length, number of internodes, leaf length and leaf breadth were found to be higher with sugarcane cultivated under drip method of irrigation when compared to flood method of irrigation (Venugopal and Rajkumar, 1998).

Table 5.2 : Yield and Water Use Efficiency under Drip and Flood Method of Irrigation

Crop	Water applied (cm)		Yield (quintal/ha)		Water saving (%)	Yield Increase (%)	Water use efficiency (q/ha/cm)	
	FMI	DMI	FMI	DMI				
Cauliflower	38.88	25.50	83.33	115.93	34.41	39.12	2.14	4.55
Tomato	101.50	69.58	45.04	58.33	31.44	29.50	0.44	0.84
Brinjal	168.00	63.90	91.00	148.20	61.99	62.86	0.54	2.32

Source : INCID (1994).

Another study carried out by Sakthi Sugar at Athagarh, Cuttack district, Orissa state found that yield of 40 tonnes per acre under DMI as against 28 tonnes per acre under FMI in sugarcane. The Benefit-Cost Ratio (BCR) of sugarcane cultivated under DMI was estimated to be 1.53 (Dash, 1998). In order to find out the response of different varieties of sugarcane under drip method of irrigation, an experimental study was conducted at the Central Sugarcane Research Station, Padegaon in Maharashtra. This study found that yield of sugarcane cultivated under DMI (111.99 tonnes/ha) was higher by 21 percent when compared to the same variety cultivated under FMI (92.43/tonnes/ha). While water use efficiency (yield in kg achieved per ha cm water) was estimated to be 999.91 for DMI, the same was estimated to be only around 391 for FMI. Besides yield increase and water saving, recovery rate of sugarcane cultivated under DMI was also found to be higher when compared to the crops cultivated under FMI (Sankpal et al., 1998).

An experiment carried out on farmers field at Wadegaon in Kukadi and Bhuinj in Krishna Commands in Maharashtra to test the impact of drip irrigation on sugarcane during 1996-97 showed an increase of yield by 28.09 to 37.02 percent under DMI over the conventional method of irrigation under different trials of testing. As mentioned by other studies due to the adoption of DMI, the recovery rate of sugarcane also considerably increased over the method of flood irrigation (Dhonde and Banger, 1998).

In order to evaluate the impact of different drip irrigation techniques on sugarcane cultivation, Vasantdada Sugar Institute (VSI) has initiated research studies along with four co-operative sugar factories located in different agro-climatic zones in Maharashtra. It came out from the research that the increase of yield was in the range of 9.23 to 23.89 percent under sub-surfaced drip systems and 8.89 to 25.35 percent under surfaced drip systems when compared to the method of conventional irrigation. The study further indicates that the automatic drip irrigation is found to be effective in increasing yield and water saving as compared to manually controlled drip irrigation and conventional method of irrigation (Deshmukh, et al., 1998).

Using the data collected from four field trials in different agro-climatic condition in Maharashtra, a study was conducted to find out the impact of drip irrigation on sugarcane cultivation (Hapase, et.al., 1992). The main conclusions of the study were, (a) water saving under DMI varied from 32 percent to 49 percent under different trials over the method of FMI; (b) yield increase varied from 22 percent to 30 percent under DMI over the method of flood irrigation, and (c) the benefit-cost ratio (BCR) of drip investment varied from 2.79 to 2.81 under different discount rates.

An observational trial conducted to find out the impact of drip irrigation (Typhoon) in sugarcane (variety COC 771) at EID Parry Farm, Nellikuppam, Tamil Nadu, indicates that the germination of the crop in Typhoon system was better by 11.5 percent over FMI. Besides water saving of about 17.7 percent, the weed population was also found to be very less under DMI when compared to FMI. However, the study has not mentioned anything about the yield gains due to drip method of irrigation (Daniel, 1992).

Under the All India Coordinated Research Project on Water Management, an important study was conducted at three different centres, namely, Rahuri, Navsari and Bhavanisagar to find out the impact of DMI on sugarcane cultivation. It was found that application of drip irrigation to sugarcane results in over 20 percent increase in yield besides a saving of 30 percent of irrigation water over the method of flood irrigation. It was also found that the adoption of DMI for sugarcane helped to gain an additional income of up to Rs. 75245/ha over the flood method of irrigation. The benefit-cost ratio was also found to be significantly higher for the crops cultivated under DMI as compared to FMI (Batta and Singh, 1998).

In order to evaluate the economic feasibility of drip system for sugarcane, feasibility studies on drip method of irrigation were conducted on heavy soils and sub-humid climatic conditions of South Gujarat region for three years during 1989-90 to 1991-92 at Soil-Water Management Farm, Gujarat Agricultural University, Navsari. The study showed that the yield of sugarcane under drip system for all the irrigation regions was significantly higher than under furrow method of irrigation. Due to the adoption of DMI, productivity of sugarcane increased by about 30 to 48 percent over the method of FMI under different drip treatment. The study also suggested an important point that a large scale adoption of drip method of irrigation in sugarcane in South Gujarat area can help to solve the problem of water logging and secondary salinization which are increasing in this regions (Parikh, et al., 1993).

It is clear from the above that the adoption of drip method of irrigation in crop cultivation not only increases water saving and productivity of crops but also reduces the cost of cultivation and weed problems. Importantly, DMI also helps to increase the germination of seed (cane) and the recovery rate of sugarcane. Though drip method of irrigation is proved to be an effective technology for increasing crop productivity, the results of research station based studies may not completely reflect the farm level problems associated with drip method of irrigation. Therefore, in the following section, an attempt is made to analyse the impact of drip method of irrigation on cost of cultivation and productivity of crops using field level data pertaining to three crops.

5.3 Cost of Cultivation - Farm Level Data

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

Studies carried out using experimental data in different crops indicate that the DMI reduces the cost of cultivation, especially in labour intensive operations like weeding, irrigation, ploughing, etc (see, INCID, 1994; Dhawan, 2002). When labour cost reduces, the total cost of cultivation also reduces because labour cost constitutes a considerable portion in the total cost of cultivation. Table 5.3 shows the operation-wise cost of cultivation per hectare for three crops for both the adopters and the non-adopters. Let us first study the cost of cultivation in sugarcane crop. It is clear from the table that drip irrigation reduces the total cost of cultivation by about Rs.6550/ha (nearly 13 percent) for the adopters as compared with the non-adopters in sugarcane crop. Though the total cost saving in terms of percentage is not very high in aggregate, it varies across different operations. Among the different operations, cost saving is very high in irrigation, furrows and bunding followed by seed and seed sowing. Saving under cost of cultivation is also found in fertilisers (about 8 percent). This is because of the reason that some of the adopters have used liquid fertilisers and thus, the cost incurred on fertilisers is relatively less. A few earlier studies have reported that drip method of irrigation also reduces the cost of fertilisers enormously as it can be supplied along with water - liquid fertilisers. Some of the farmers have argued that even without using liquid form of fertilisers, the same can be reduced by avoiding wastage under drip method of irrigation. Since water is supplied through pipe network under drip method of irrigation, it does not require more labour.[19] But, in the case of surface method of irrigation, labour input is necessary to control water supply (changing course of water from one field to other) and to govern leakage and seepage. In addition to saving in cost of labour, cost incurred on account of electricity (for operating pump-set) is also less as drip requires less amount of water when compared to flood method of irrigation. Saving under cost of cultivation is noticed in ploughing and preparatory operation by about 17 per cent. This is because of the fact that drip method of irrigation does not warrant much ploughing as it supplies water at the root zone of the crops. As indicated by earlier studies, the cost saving is also very high in weeding operation, which comes to about 12 percent over the cost incurred by the farmers who cultivated sugarcane under FMI. Cost saving in weeding operation is high because it does not allow weed to come up in the non-crop space by not supplying water beyond the root zone of the crop. It should, however, be noted that the cost of cultivation varies with situational factors like soil quality, condition of the terrain, farmers' approach, etc.

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

Table 5.3 : Cost of Cultivation of the Adopters and the Non-Adopters of Drip Method of Irrigation

(Rs/ha)

Sr. No.	Operations	Sugarcane			Grapes			Banana		
		DMI	FMI	% change over FMI	DMI	FMI	% change over FMI	DMI	FMI	% change over FMI
1.	Ploughing and Preparation	3385.10	4087.40	-17.18	5917.78	6130.99	-3.48	2633.22	3223.31	-18.30
2.	Furrows and Bunding	1433.10	1836.80	-21.98	IUPP	IUPP	—	IUPP	IUPP	—
3.	Seed and Seed Sowing	7155.00	8515.80	-15.98	DNC	DNC	—	5331.41	5415.79	-1.56
4.	Fertilizers (in-organic)	9396.20	10252.70	-8.35	21828.02	25329.28	-13.83	16377.66	17493.63	-6.38
5.	Farm Yard Manure	6939.50	7434.00	-6.65	13273.02	16410.16	-19.12	9974.64	8315.87	19.95
6.	Pesticides	990.80	972.50	1.88	47695.42	50107.37	-4.81	9.87	—	—
7.	Weeding and Interculture	4583.10	5208.40	-12.00	7782.28	8854.69	-12.11	1825.66	2122.88	-14.00
8.	Irrigationa	5676.40	7195.00	-21.11	8585.82	8428.82		5756.70	6378.68	-9.75
9.	Harvesting	b	b	—	14255.93	11907.66	19.72	4612.66	5546.94	-16.84
10.	Transport and Marketing	b	b	—	3966.42	5322.12	-25.47	2706.08	2346.49	15.32
11.	Others	2434.00	3037.28	-19.86	11201.50	14423.76	-22.34	2207.24	1895.04	-16.47
12.	Total Cost of Cultivation	41993.20	48539.88	-13.49	134506.19	147914.96	-9.07	51436.66	52738.56	-2.47

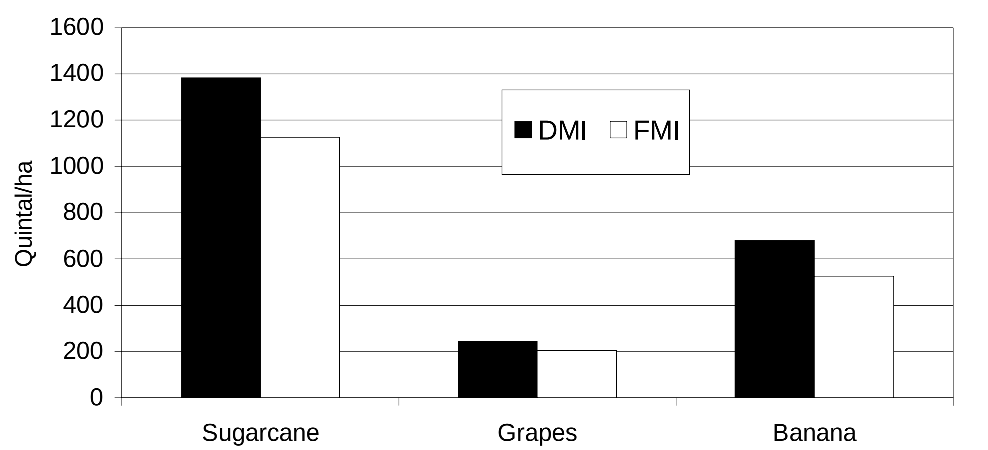
Notes : a - Includes operation and maintenance costs of pump set and drip set; b - Costs of harvesting, transport and marketing are not included since sugar factories have incurred these costs; IUPP - Included under ploughing and preparation; DNC - Relevant data could not be collected as grape gardens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

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

As in the case of sugarcane, farmers who cultivated grapes and banana under DMI have also incurred relatively lower cost of cultivation. In the case of banana, drip irrigation reduces the total cost of cultivation by about Rs. 1300/ha as compared to the farmers who cultivated the same crop under flood method of irrigation. Among the different operations, cost saving is very high in the cost of irrigation. Second highest saving under cost of cultivation is noticed in ploughing operation. As mentioned earlier, this is because of the fact that drip method does not warrant much ploughing as it supplies water at the root zone of the crops. The cost saving is also high in weeding operation as indicated by earlier studies.

The reduction in cost of cultivation in grapes is relatively higher as compared to banana. In banana, cost saving due to DMI was only about 2.50 percent, whereas the same is nearly 10 percent in grapes. As in the case of banana crop, cost saving varies with operations in grapes as well. Cost saving is found to be higher in operations like weeding, irrigation, fertilisers and ploughing. On the whole, cost saving due to drip method of irrigation is found in most of the operations. Major difference in cost of cultivation between the adopters and the non-adopters is observed in irrigation, weeding and inter-culture, ploughing and preparation, and seed and sowing.

Figure 5.1 : Producivity Difference - Drip versus Flood Irrigated Crops



5.4 Productivity Gains from Drip Irrigation

One of the important advantages of drip method of irrigation is productivity gain. Generally, productivity of a crop is directly related with the amount of use of yield increasing inputs besides source of irrigation. Productivity of canal irrigated crops is higher than the tank irrigated crops. Similarly, productivity of crops, which are cultivated using groundwater irrigation, is much higher than canal and tank irrigated crops (Dhawan, 1988; Vaidyanathan, et al., 1994). Most of the time, yield is affected because of moisture stress faced by crops. It is difficult to maintain the water supply constantly for crops by surface method of irrigation due to various reasons. Studies related to drip method irrigation have confirmed that problem of moisture stress is completely reduced by providing irrigation through drip as it supplies water at the root zone of the crops at a required frequency and quantity. As a result, the yield of crops cultivated under drip method of irrigation is much higher than the crops which are cultivated under the method of surface irrigation.

Table 5.4 : Productivity of Crops under Drip and Flood Irrigated Condition

Crop	Productivity (quintal/ha)		Productivity increase over FMI	
	DMI	FMI	Percent	Quantity
Sugarcane	1383.60	1124.40	23.05	259.20
Grapes	243.25	204.29	19.07	38.96
Banana	679.54	526.35	29.10	153.19

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

As expected, productivity is significantly higher for the farmers who have adopted drip method of irrigation as compared to the non-drip adopters in all the three crops selected for analysis (Table 5.4). The yield difference in absolute term between the adopters and the non-adopters of drip method of irrigation comes to nearly 259 quintals per hectare for sugarcane. In terms of percentage, productivity of sugarcane cultivated under drip method of irrigation is higher by about 23 percent. In the case of grapes, the productivity difference between DMI and FMI adopter comes to about 19 percent and the same comes to 29 percent in the case of banana crop (see, Figure 5.1). The important point to be underlined here is that despite incurring more cost on yield increasing inputs, productivity of crops cultivated under FMI is significantly lower than that of DMI. There are three main reasons for higher yield in drip irrigated crops. First, because of less moisture stress, the growth of crops cultivated under DMI was good which ultimately helped to increase the productivity.

Second, unlike surface method of irrigation, drip does not encourage any growth of weed, especially in the non-crop zone. Weeds consume considerable amount of yield increasing inputs and reduce the yield of crops in surface method of irrigation. Third, unlike surface method of irrigation, fertiliser losses occurring through evaporation and leaching through water are less under drip method of irrigation as it supplies water only for crop and not for the land. Though the expenditures incurred by the non-adopters on different yield increasing inputs are more than the adopters in all three crops, this does not coincide with increased yield of crops. Therefore, one can conclude that this productivity enhancement in all three crops is because of drip method of irrigation.

Table 5.5 : Expenditure Incurred to Produce one quintal of Output under Drip and Non-Drip Irrigated Condition

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Yield (quintal/ha)	1383.60	1124.40	243.25	204.29	679.54	526.35
Cost of cultivation (Rs/ha)	41993.20	48539.88	134506.19	147914.96	51436.66	52738.56
Cost of Production (Rs/quintal)	30.35	43.17	552.95	724.04	70.69	100.19

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

Besides increasing productivity of crops, DMI also increases the cost efficiency, i.e., it reduces the cost required to produce an unit of crop output. In order to understand the cost efficiency of drip and non-drip irrigated crops, we have calculated expenditure incurred to produce one quintal of output for both the adopters and the non-adopters. Per quintal cost is calculated by dividing the total cost of cultivation with per hectare yield of three crops. It is evident from Table 5.5 that the non-adopters spend nearly Rs.13 over the adopters to produce every quintal of sugarcane in Maharashtra. Likewise, in grapes, the non-adopters have incurred over Rs. 171 per quintal over the adopters and in banana, the non-adopters have incurred nearly Rs. 30 to produce one quintal of output over the counterpart. This clearly indicates that apart from increasing the productivity of crops, drip method of irrigation also increases cost efficiency substantially than the flood method of irrigation. On the whole, the analysis carried out using both the experimental and field level data clearly suggests that drip method of irrigation increases productivity of crops that too with reduced cost of cultivation.

Chapter 6

Benefit-Cost Analysis

6.1 Introduction

It is clear from the preceding chapters that drip method of irrigation reduces cost of cultivation, saves substantial amount of water and electricity and also enhances productivity of crops. Despite this, one of the important questions often asked about the drip method of irrigation is whether or not drip investment is economically viable to farmers cultivating crops using this new water saving technology. This question arises mainly because of two reasons. First, drip method of irrigation requires relatively large amount of fixed investment to install it in the field and therefore, everyone (from policy makers to farmers) wants to know its economic viability. Second, though DMI has been in use over the last one decade in Indian agriculture, not many credible studies are available focusing on the economic viability of drip investment, especially using data collected from farmers' field. In view of this, there is a need to evaluate the economic viability of drip investment in drip-irrigated crops. In this chapter, therefore, an attempt is made to analyse the economic viability of drip investment using both secondary and primary level information.

6.2 Benefit-Cost Estimates - Secondary Sources

Though quite a few studies have analysed the impact of drip method of irrigation on different parameters, not many studies have attempted to look into the economic viability of drip investment even by using experimental data. Some estimates on benefit-cost ratios are available from three secondary sources namely INCID (1994); Sivanappan (1995) and AFC (1998). While it is not clear whether the estimates available in these three studies are carried out using discounted cash flow technique, let us discuss the results of these studies before going into analyse the estimates made using field survey data.

The capital cost required for installing drip system for different crops has been increasing over the years due to increase in the cost of materials used for manufacturing the drip system (GOI, 2004). The capital cost of drip system largely depends upon the type of crop (whether narrow or wide spaced crops), spacing followed for cultivating crops, proximity to water source (distance between the field and source of water) and the materials used for the system. Wide spaced crops generally require less capital when compared to the crops having narrow space, as the latter would require more laterals and drippers per hectare. INCID (1994) results reported in Table 6.1 clearly indicate that the requirement of capital cost is much higher for banana (Rs. 33765/ha) as compared to the same required for mango (Rs. 11053/ha), which is a wide spaced crop.

Table 6.1 : Benefit-Cost Ratio of Different Drip Irrigated Crops

Name of the Crop	Spacing (m x m)	Capital Cost (Rs/ha)	Benefit-Cost Ratio	
			Excluding Water Saving	Including Water Saving
Coconut	7.62 x 7.62	11053	1.41	5.14
Grapes	3.04 x 3.04	19019	13.35	32.32
Grapes	2.44 x 2.44	23070	11.50	27.08
Banana	1.52 x 1.52	33765	1.52	3.02
Orange	4.57 x 4.57	19859	1.76	6.01
Pomegranate	3.04 x 3.04	19109	1.31	4.40
Mango	7.62 x 7.62	11053	1.35	8.02
Papaya	2.13 x 2.13	23465	1.54	4.01
Sugarcane	Between biwall 1.86	31492	1.31	2.78
Vegetables	Between biwall 1.86	31492	1.35	3.09

Source : Compiled from INCID, (1994).

As regards B-C ratio, the results available from INCID (1994) show that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account subsidy given to farmers. The B-C ratio estimated excluding water saving varies from 1.31 in sugarcane to as high as 13.35 in grapes. Obviously, the B-C ratio increases significantly further, when it is estimated after including water saving. Various case studies reported in INCID (1994) also indicate that investment in drip irrigation is economically viable for different crops (see, Tables 6.2 and 6.2A). Similar to INCID (1994), Sivanappan (1995) also estimated B-C ratio for different crops cultivated under DMI using data pertaining to the year 1993. It also suggests that the investment in drip irrigation is economically viable for different crops since the B-C ratio estimated was more than one. While the B-C ratio for pomegranate was estimated to be 5.16, the same is estimated to be 1.83 for cotton, which is a less-water intensive as well as a narrow spaced crop.

Table 6.2 : Cost-Benefit of Different Crops under DMI and FMI

Sr. No	Particulars	Banana		Chilli		Cucumber		Grapes		Groundnut	
		DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI
1	Fixed Cost (Rs)	30000	Nil	32500	Nil	32500	Nil	32500	Nil	32000	Nil
	a) Life (years)	5	Nil	6	Nil	10	Nil	10	Nil	5	Nil
	b) Depreciation	6000	Nil	5417	Nil	3250	Nil	3250	Nil	6400	Nil
	c) Interest	1800	Nil	1950	Nil	1950	Nil	1950	Nil	1920	Nil
	d) Repairs and Maintenance	600	Nil	650	Nil	650	Nil	650	Nil	640	Nil
	e) Total (b+c+d)	8400	Nil	8017	Nil	5850	Nil	5850	Nil	8960	Nil
2	Cost of Cultivation (Rs/ha)	34600	40000	8935	10600	9800	11300	51000	60000	6650	7450
3	Seasonal total Cost (1e+2) (Rs/ha	43000	40000	16952	10600	15650	11300	56850	60000	15610	7450
4	Water Used (mm.)	970	1760	290	780	363	600	278	532	580	900
5	Yield of Produce (q/ha)	875	575	29	20	255	180	325	264	32	16.75
6	Selling Price (Rs/q)	300	300	2000	2000	200	200	1500	1450	800	800
7	Income from produce (5 x 6) (Rs)	262500	172500	58000	40000	51000	36000	487500	322800	25600	13400
8	Net seasonal income (7-3) (Rs)	219500	132500	41048	29400	35350	24700	430650	322800	9990	5950
9	Additional area cultivated due to saving of water (ha)	0.80	Nil	1.50	Nil	0.65	Nil	0.90	Nil	0.50	Nil
10	Additional expenditure due to Additional area (3 x 9)	34400	Nil	25428	Nil	10172.50	Nil	51165	Nil	7805	Nil
11	Additional income due to additional area (7 x 9)	210000	Nil	87000	Nil	33150	Nil	438750	Nil	12800	Nil
12	Additional Net income (11-10) (Rs)	175600	Nil	61572	Nil	22977.50	Nil	387585	Nil	4995	Nil
13	Gross cost of production (3+10)(Rs)	77400	40000	42380	10600	25822.50	11300	108015	60000	23415	7450
14	Gross income (7+11) (Rs)	472500	172500	145000	40000	84150	36000	926250	382800	38400	13400
15	Gross benefit cost ratio (14/13)	6.10	4.31	3.42	3.77	3.26	3.19	8.58	6.38	1.64	1.80
16	Net extra income due to drip Irrigation system over conventional (12+8 drip - 8 conventional)	262600	Nil	73220	Nil	58327.50	Nil	495435	Nil	9035	Nil
17	Net Profit per mm of water used (8/4)	226.29	75.28	141.55	37.69	97.38	41.17	1549.10	606.77	17.22	6.61
18	Water use efficiency (5/4 x 100)kg/ha mm	90.21	32.67	10	2.56	70.25	30	116.91	49.62	5.52	1.86

Source : INCID (1994).

Table 6.2A : Cost-Benefit of Different Crops under DMI and FMI

Sr. No	Particulars	Mosambi		Pomegranate		Sugarcane (M)		Tomato		Watermelon	
		DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI
1	Fixed Cost (Rs)	20000	Nil	18000	Nil	30000	Nil	32500	Nil	33700	Nil
	a) Life (Years)	10	Nil	5	Nil	5	Nil	10	Nil	10	Nil
	b) Depreciation	2000	Nil	3600	Nil	6000	Nil	3250	Nil	3370	Nil
	c) Interest	1200	Nil	1080	Nil	1800	Nil	1950	Nil	2022	Nil
	d) Repairs and Maintenance	400	Nil	360	Nil	600	Nil	650	Nil	674	Nil
	e) Total (b+c+d)	3600	Nil	5040	Nil	8400	Nil	5850	Nil	6066	Nil
2	Cost of Cultivation (Rs/ha)	3800	5400	17500	12500	11445	17375	11440	13000	10240	11790
3	Seasonal total Cost (1e+2) (Rs/ha	7400	5400			19845	17375	17290	13000	16306	11790
4	Water Used (mm)	640	1660	785	1440	940	2150	184	300	210	330
5	Yield of Produce (q/ha)	150000	100000	109	75	1700	1280	480	320	450	240
6	Selling Price (Rs/q)	0.74	0.53	1000	750	31	30	150	150	200	200
7	Income from produce (5x6) (Rs)	111000	53000	10900	27500	52700	38400	72000	48000	90000	48000
8	Net seasonal income (7-3) (Rs)	103600	47600	86460	15000	32855	21025	54710	35000	73694	36210
9	Additional area cultivated due to saving of water (ha)	1.50	Nil	0.80	Nil	2	Nil	0.60	Nil	0.50	Nil
10	Additional expenditure due to Additional area (3x9)	11100	Nil	18032	Nil	39690	Nil	10374	Nil	8153	Nil
11	Additional income due to additional area (7x9)	166500	Nil	87200	Nil	105400	Nil	43200	Nil	45000	Nil
12	Additional Net income (11-10) (Rs)	155400	Nil	69168	Nil	65710	Nil	32826	Nil	36847	Nil
13	Gross cost of production (3+10)(Rs)	18500	5400	40572	12500	59535	17375	27664	13000	24459	11790
14	Gross income (7+11) (Rs)	277500	53000	196200	27500	158100	38400	115200	48000	135000	48000
15	Gross benefit cost ratio (14/13)	15	9.81	4.84	2.20	2.66	2.21	4.16	3.69	5.52	4.07
16	Net extra income due to drip Irrigation system over conventional (12+8 drip - 8 conventional)	211400	Nil	140628	Nil	77540	Nil	87536	Nil	110541	Nil
17	Net Profit per mm of water used (8/4)	161.88	28.67	110.14	10.42	34.95	9.78	297.34	116.67	350.92	109.73
18	Water use efficiency (5/4x100)kg/ha mm	23437.50	6024.10	138.9	52	180.85	59.53	260.87	106.67	214.29	72.73

Source : INCID (1994).

Unlike the results reported in INCID (1994) and Sivanappan (1995), AFC (1998) has estimated B-C ratio using field survey data collected from 3850 sample farmers, consisting of beneficiary and non-beneficiary farmers. The survey covered 26 sample districts in six states. While the B-C ratio provided in AFC (1998) does not show the picture clearly, using the same data Dhawan (2002) has estimated B-C ratio for different crops at 12 percent discount rate, which are reproduced in Table 6.3. Though the B-C ratio appears to be very high, it is found to be relatively higher in all those districts belonging to Maharashtra state as compared to the districts considered from other states. The inter-district variation in B-C ratio is possibly because of inter-districts variation in crop composition. The overall B-C ratio for the 21 sample districts presented in the table for a drip investment of Rs. 27000 is about 10, which is by any measurement extremely very high and attractive (Dhawan, 2004).

Table 6.3 : AFC District Level Estimates of Benefit-Cost Ratio

Sr. No. State/District	Drip Capital Cost (Rs/ha)	Drip O & M Cost (Rs/ha)	Benefits (Rs/ha)	B-C Ratio when Drip Life is	
				5 years	10 years
I. Maharashtra :					
1. Ahmednagar	26883	1154	93240	10.83	15.79
2. Amravati	15455	540	57309	11.87	17.50
3. Aurangabad	22285	682	74567	10.86	16.12
4. Dhule	23543	1058	170007	22.40	32.54
5. Jalgaon	34385	1265	97221	9.00	13.23
6. Kolhapur	23626	1167	127487	16.51	23.84
7. Nasik	29413	1056	198933	21.59	31.77
8. Pune	42396	1429	121128	9.18	13.56
9. Sangli	49965	1541	150854	9.79	14.53
10. Solapur	31835	1096	105106	10.59	15.62
II. Andhra Pradesh :					
1. Chittoor	16158	240	33185	7.03	10.71
2. Nellore	16504	188	29593	6.21	9.52
3. Rangareddy	12488	279	28947	7.73	11.63
III. Karnataka :					
1. Belgaum	41485	557	112444	9.32	14.23
2. Bijapur	25109	353	68993	9.43	14.38
3. Chitradurga	30765	324	83038	9.37	14.39
4. Shimoga	31652	1179	75269	7.56	11.10
5. Tumkur	23073	662	49341	6.99	10.40
IV. Tamil Nadu :					
1. Chengalpattu	25793	459	67453	8.46	12.83
2. Coimbatore	20443	363	44519	7.38	11.18
3. Periyar	18395	327	41108	7.57	11.47

Source : Adapted from Dhawan (2002).

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

6.3 The Approach on Benefit-Cost Analysis

As mentioned earlier, past studies (e.g. INCID, 1994; Sivanappan, 1994; AFC, 1998) on the subject have either conducted benefit-cost analysis without a proper methodology or relied heavily on the experience of one or few farmers adopting DMI. Therefore, there is a need for a study to empirically evaluate the economic viability of DMI within a relatively more systematic methodological framework. Specifically, we try to address (1) how the factors like fixed investment influence economic viability on DMI and (2) how government subsidies and farmers' time preference (i.e., the differential discount rates) influence the economic viability of DMI in three crops namely sugarcane, grapes and banana.

In order to evaluate the economic viability of drip investment in the context of three crops, we have computed both the Net Present Worth (NPW) and the Benefit-Cost Ratio (BCR) by 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 drip set can be treated as economically viable if the present value of benefits is greater than the present value of costs. The BCR is also related to NPW as it is obtained just by dividing the present worth of the benefit stream with that of the cost stream. Generally, if the

BCR is more than one, then, the investment on that project can be considered as economically viable. A BCR greater than one obviously implies that the NPW of the benefit stream is higher than that of the cost stream (Gittinger, 1984). The NPW and BCR can be defined as follows:

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

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

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

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

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

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

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

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

6.4 Capital Cost, Production Cost and Gross Income

As a backdrop to our benefit-cost analysis of DMI, we first briefly discuss about the gross cost of production, profit without discount, capital cost (without and with subsidy) and the amount of subsidy received by the farmers. Table 6.4 presents the details of production, gross income and other details for three crops namely sugarcane, grapes and banana. To complete the analysis of the relative economics of DMI and FMI, we have calculated the relative profit levels of three crops for the adopters and non-adopters of DMI. Profit of a crop is not only determined by its total quantity of output but also its quality. Prevailing market conditions also plays a crucial role in determining the price of agricultural commodities. A good quality product can fetch better price in the market. It has come out from the earlier studies that drip method of irrigation not only helps in increasing the yield of the crops but also improves quality of the product and fetches higher price in the market (INCID, 1994; Sivanappan, 1994; Narayanamoorthy, 1997a, b).

Let us study how profit (undiscounted) varies between drip and non-drip irrigated crops in our study. While calculating profit, the total cost was calculated by considering only the variable costs but not the fixed cost components like interest rate and depreciation.[20] To calculate per hectare profit, we subtract the total cost of cultivation from the total income for the group of adopters and the non-adopters. The gross income (in rupees) is calculated by multiplying total yield with price received by the farmers for their crop output. It can be seen from Table 6.4 that per hectare profit[21] of the adopters in sugarcane is Rs. 27424 higher than that of the non-adopters. In terms of percentage, profit of the drip adopters is higher by about 74 percent over the profit of the non-drip farmers. This is not surprising because on the one hand drip irrigation reduces the cost of cultivation of sugarcane and on the other hand it increases the yield of sugarcane.

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20. The cost of cultivation used in our analysis refers to cost A_2, which includes all actual expenses in cash and kind incurred in production by owner plus rent paid for leased-in land. See, CACP (1998) for more details about different cost concepts.

21. This profit is calculated by deducting gross income from cost A_2.

Some studies have indicated that since moisture stress is very less for the crops cultivated under DMI, the quality of crop produce cultivated under DMI is good which ultimately helps to fetch higher price in the market. We could not test this in our study because all the farmers have supplied sugarcane to sugar factories, where the price is uniformly fixed for all the farmers. However, some of the adopters have argued that if recovery testing is done separately for drip-irrigated sugarcane, the real impact of DMI on recovery rate of sugarcane can be visibly seen.[22] Therefore, under these circumstances, we can conclude that farmers adopting drip method of irrigation earn more profit not because of price effect but only because of yield effect.

Similar to sugarcane crop, the average profit among the drip adopters is significantly higher than that among the non-drip adopters in case of both grapes and banana. It can be seen from Table 6.4 that 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. While the profit differential is substantial for drip irrigated crops, it cannot be taken as a conclusive indicator of the comparative advantages of the new irrigation technique as our profit calculation is based only the variable cost but ignores fixed cost components like depreciation and interest accrued on the fixed capital while calculating the net profit. The life period of drip-set is one of the important variables which determine the per hectare profit. Moreover, since it is a capital-intensive technique, the huge initial investment needed for installing drip systems remains the main deterrent for the widespread adoption of DMI. To what extent this discouragement effect is real and to

22. A scientific study carried out jointly by Jain Irrigation Systems Limited (JISL), Jalgaon and Sakthi Sugars Limited (SSL), Sivagangai, in a farmer's field (Shri K.K.R. Tamilarasu of Chokkanathapuram village) at Sivagangai district, Tamil Nadu shows that the recovery rate of sugarcane cultivated under DMI (12.16 percent) is about 0.35 percent points higher than that of flood irrigated sugarcane (11.81 percent). The author is thankful to both JISL and SSL for sharing the results of their scientific study. The other parameters of the scientific study are presented below for the purpose of comparison:

Details	No. of IN	IN Length (cm)	Cane girth (cm)	Cane length (m)	IN cane weight (kg)	NMC/acre (numbers)	Brix Juice) %	Pol (sucrose) %	Purity %	Recovery %	Yueld (tonne/acre)	CCS (tonne/acre)
DMI	33	9.87	2.79	3.26	2.01	53568	19.21	17.07	88.90	12.16	59.00	7.17
FMI	30	8.17	2.67	2.41	1.61	45953	19.86	16.78	86.67	11.81	36.00	4.25

Notes : IN - internodal; NMC - net millable canes; CCS - commercial cane sugar.

what extent such effect can be counterbalanced by government subsidy are some of the important policy issues requiring empirical answers.

Fixed capital is needed for installing drip method of irrigation. The magnitude of capital requirement varies with crop depending upon certain factors as indicated earlier. Generally, wide spaced crops require relatively low fixed investment and narrow spaced crops need higher fixed investment. 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 water source (well) and the field (NABARD, 1989). Let us now evaluate the empirical pattern of capital cost of the drip system, production cost (cost of cultivation) of crops and the amount of subsidy received by the sample farmers. Table 6.4 presents the details of capital cost and subsidy for all three crops. As mentioned earlier, since DMI is a capital-intensive technology, government provides nearly 50 percent of the capital cost as subsidy to encourage the adoption of drip irrigation in crop cultivation. The average capital subsidy comes to Rs. 19263/ha for sugarcane, Rs. 11359/ha for grapes and Rs. 12620/ha for banana. As a proportion of the total capital cost of drip set, subsidy amount accounts for about 35 to 37 percent among three crops, which is within a limit of provision made by the government. With this background, let us analyse benefit-cost pattern of drip investment using discounted cash flow technique.

Table 6.4 : Capital Cost, Production Cost, Gross Income, Subsidy among Drip and non-Drip Irrigated Crops

Particulars	Sugarcane		Grapes		Banana	
	DMI	FMI	DMI	FMI	DMI	FMI
Cost of cultivation (Rs/ha)[a]	41993.20	48539.88	134506.19	147914.96	51436.66	52738.56
Gross income (Rs/ha)	106366.00	85488.20	247817.02	211037.97	134043.75	102934.73
Profit (Rs/ha)[b] (Farm business income)	64372.80	36948.32	113310.83	63122.97	82607.09	50196.17
Capital cost of drip set (Rs/ha) (without subsidy)[c]	52811.00	—	32721.00	—	33595.00	—
Capital cost of drip set (Rs/ha)(with subsidy)[c]	33547.56	—	20101.00	—	22236.00	—
Subsidy (Rs/ha)	19263.44	—	11359.00	—	12620.00	—

Notes : a - production cost (A_2) includes the operation and maintenance cost of drip set and pump-set; b - This is the difference between gross value of production and production cost (A_2) and c - it does not include pump-set cost.

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

6.5 Benefit-Cost Analysis

Though all the sample farmers (adopters) in our survey have received subsidy for installing drip technology for all three crops through government schemes, we have computed both the NPW and the BCR separately by including and excluding subsidy in the total fixed capital cost of drip set. This is done to assess the potential role that subsidy plays in the adoption of DMI. 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 6.5 presents the results of sensitivity analysis for sugarcane crop 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.

Table 6.5 : Net Present Worth and Benefit Cost Ratio for Drip Irrigated Sugarcane under With and Without Subsidy Condition

Sr. No.	Particulars	Without Subsidy	With Subsidy
1.	Present Worth of Gross Income (Rs/ha)		
	At 15 percent discount rate	356645.20	356645.20
	At 12 percent discount rate	412902.28	412902.28
	At 10 percent discount rate	434205.99	434205.99
2.	Present Worth of Gross Cost (Rs/ha)		
	At 15 percent discount rate	186748.77	169989.58
	At 12 percent discount rate	198545.71	181343.46
	At 10 percent discount rate	207254.23	189724.50
3.	Net Present Worth (Rs/ha)		
	At 15 percent discount rate	169896.43	186655.63
	At 12 percent discount rate	214356.57	231558.82
	At 10 percent discount rate	226951.76	244481.49
4.	Benefit Cost Ratio :		
	At 15 percent discount rate	1.909	2.098
	At 12 percent discount rate	2.079	2.277
	At 10 percent discount rate	2.095	2.289

Source : Computed using Narayanamoorthy (2001).

Let us first discuss about sugarcane crop. As expected, the NPW of the investment with subsidy is marginally higher than that under 'no subsidy' option. For instance, at 15 percent discount rate, the NPW of drip investment is about 169896/ha without subsidy but Rs.186655/ha with subsidy. This means that the subsidy enables the farmers to get an additional benefit of Rs. 16759/ha. It can also be observed that the difference between the NPW under 'with subsidy' and 'no subsidy' scenarios is decreasing along with each increase in discount rate. For instance, the NPW under without subsidy condition increased from Rs. 169896/ha. at 15 percent discount rate to Rs. 226951/ha. at 10 percent discount rate. Similarly, under subsidy condition, the NPW increased from Rs. 186655/ha at 15 percent discount rate to Rs. 244481/ha. at 10 percent discount rate. Similar to this, under without subsidy condition, the BCR also increased marginally from 1.909 at 15 percent discount rate to 2.095 at 10 percent discount rate. The higher BCR under subsidy condition suggests the positive role that subsidy plays in improving the economic viability of drip method of irrigation in sugarcane.

Similar to sugarcane crop, the NPW and BCR are estimated separately for banana and grapes. Table 6.6 presents the results of the 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 both banana and grapes. For instance, at 15 per cent discount rate, the NPW of drip investment for banana is about Rs. 247753/ha without subsidy but Rs. 2,57,635/ha with subsidy. This means that the subsidy enables farmers to get an additional

Table 6.6 : Net Present Worth and Benefit Cost Ratio for Drip Irrigated Grapes and Banana under With and Without Subsidy Condition

Sr. No.	Particulars	Without Subsidy		With Subsidy	
		Banana	Grapes	Banana	Grapes
1.	Present Worth of Gross Income (Rs/ha)				
	At 15 percent discount rate	449449	1243794	449449	1243794
	At 12 percent discount rate	483228	1400166	483228	1400166
	At 10 percent discount rate	508026	1522588	508026	1522588
2.	Present Worth of Gross Cost (Rs/ha)				
	At 15 percent discount rate	201696	703553	191814	692574
	At 12 percent discount rate	215431	789179	205287	777909
	At 10 percent discount rate	225484	856148	215159	844677
3.	Net Present Worth (Rs/ha)				
	At 15 percent discount rate	247753	540241	257635	551220
	At 12 percent discount rate	267797	610987	277941	622257
	At 10 percent discount rate	282542	666440	292867	677911
4.	Benefit Cost Ratio :				
	At 15 percent discount rate	2.288	1.767	2.343	1.795
	At 12 percent discount rate	2.243	1.774	2.353	1.799
	At 10 percent discount rate	2.253	1.778	2.361	1.802

Source : Computed from Narayanamoorthy (1996 and 1997).

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 the Table 6.6, the BCR without subsidy for banana 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.

Another policy wise 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 year-wise computation of NPW for sugarcane, banana and grapes clearly shows that farmers can recover the entire capital cost of the drip set from their net profit in the very first year itself. This finding contradicts with the general belief that the capital cost recovery for drip investment takes more time. More importantly, when farmers can recover the capital costs within a year, the role of discount rate as a device to capture the time preference of farmer seems to be of considerably lesser importance than one might think. However, in order to have a more definite answers 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, lower soil degradation and retention of soil fertility as well as the social costs in terms of the negative food and fodder in the crop pattern shift and labour displacement. On the whole, the BCR under different discount rates indicates that drip investment in three crops considered for detailed analysis remains economically viable even without subsidy.

Chapter 7

Potential and Prospects for Drip Irrigation in India

7.1 Introduction

It is clear from the foregoing chapters that drip method of irrigation has many advantages over the flood method of irrigation, which is predominantly followed in most of the countries. Despite the fact that drip method of irrigation involves relatively larger fixed investment, benefit-cost ratio estimated using farm level data clearly suggests that the investment in drip irrigation is economically viable to farmers. Although the drip method of irrigation has proved to be a very useful method for sustainable use of irrigation water, not many studies have attempted to estimate the total potential area for drip method of irrigation as well as the total potential water saving that can be realised by utilising the potential area for India as a whole.[23] Besides helping to understand the overall potential of the country, this kind of estimate would be useful for making policy decision, fixing targets and allocation of funds for utilising the potential. It is in this context, in the present chapter, we try to provide answers to questions like : what would be the total potential of the drip irrigated area and the required investment for utilising this potential? How much water can be saved by utilising the potential area? How much additional irrigated area can be created from the saving of water by adopting DMI?

7.2 Potential Area for Drip Method of Irrigation

India has enormous potential for drip method of irrigation. Potential area for DMI is also expected to increase faster due to fast decline of irrigation potential. Various crops that are highly suitable for drip method of irrigation are extensively cultivated in different parts of India. Available information shows that about 80 crops, both narrow and wide spaced crops, can be grown under drip method of irrigation in India (see, Table 7.1). Due to various measures taken by the central and state governments along with the support of drip-set manufactures, the area under DMI has increased phenomenally in recent years. However, the achievement of area seems to be very less compared to the total potential area that exists in India.

23. At the macro level, there are two estimates available on the potential area for drip method of irrigation in India. While the NCPA (1990) estimated about 18.20 mha as a potential area for DMI, the Task Force on Micro-Irrigation (GOI, 2004) estimated about 27 mha as a potential area for the country as a whole. However, both the sources have not provided any explanation about the method that is followed for estimating the potential area.

Table 7.1 : Crops Grown under Drip Method of Irrigation

I. CEREALS	39. Mango
1. Corn	40. Mosambi
2. Sorghum	41. Naval Orange
3. Wheat	42. Papaya
II. FLOWERS	43. Peach
4. Chrysanthemum	44. Pear
5. Camation	45. Pineapple
6. Jasmine	46. Persimmon
7. Rose	47. Plum
8. (All) Ornamental Trees and Shrubs	48. Pomegranate
III. FODDERS	49. Strawberry
9. Alfalfa	50. Tangelo
10. Asparagus	51. Tangerine
11. (All) Pastures	52. Valencia Orange
IV. FIBRES	53. Watermelon
12. Cotton	*VIII. PLANTATION CROPS*
13. Sisal	54. Bamboo
V. NUTS	55. Cocoa
14. Almond	56. Coffee
15. Arecanut	57. Mulberry
16. Cashew nut	58. Oil palm
17. Coconut	59. Rubber
18. Macadmaia	60. Sugarcane
19. Walnut	61. Tamarind
VI. OILSEEDS	62. Tapioca
20. Groundnut	63. Tea
VII. ORCHARDS	64. Teak
21. Amla	*IX. SPICES*
22. Apple	65. Cardamom
23. Apricot	66. Pepper
24. Avocado	*X. VEGETABLES*
25. Banana	67. Beet Root
26. Ber	68. Brinjal
27. Betelvine	69. Bulbs
28. Boysen Berry	70. Celery
29. Cherry	71. Chilli
30. Chikoo (Sapota)	72. Cucumber
31. Citrus	73. Egg Plant
32. Custard Apple	74. Lettuce
33. Fig	75. Onion
34. Grape (Table and Wine)	76. Peas
35. Grape fruit	77. Potato
36. Guava	78. Radish
37. Lemon	79. Sweet Potato
38. Lime	80. Tomato

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

DMI is not only suitable for those areas that are presently under cultivation, but it can also be operated efficiently in undulating terrain, rolling topography, hilly areas, barren lands and areas which have shallow soils (Sivanappan, 1994). Since most of the potential areas are not under cultivation presently, we can broadly divide the total potential into two categories as "distant potential" and "core potential" for the purpose of analysis. "Distant potential" refers to all those areas that are suitable for drip method of irrigation, but may not be under cultivation presently. Lands (area) that are falling under the categories of barren and unculturable lands, culturable wastelands and fallow lands can be treated as "distant potential" of DMI. In India, as per the land utilisation data of 1994-95, about 56.28 million hectares of lands are available in these categories. Unlike FMI, land-leveling and ploughing are not necessary for cultivating crops (especially horticultural crops) under DMI. Therefore, without incurring heavy expenditures on land reclamation activities, these areas can be brought under cultivation using drip method of irrigation in a phased manner by a properly designed special development programme.

Table 7.2 : Drip Irrigation Potential and Capital Requirement - India

Crop's Name	Potential Area (million hectares)		Capital (Rs/ha)	Requirement of Capital (Rs. Crore)	
	Core*	Net**		For Core Potential	For Net Potential
Oilseeds (except groundnut)	18.09	5.17	40000[a]	72360	20680
Sugarcane	4.23	4.23	31492[b]	13321	13321
Vegetables	5.34	5.34	40000[c]	21360	21360
Fruits	3.36	1.20	27543[d]	9254	3305
Tea	0.45	—	25000[e]	1125	—
Coffee	0.30	—	25000[e]	750	—
Tobacco	0.48	—	40000[f]	1920	—
Condiments and Spices	2.65	1.00	31492[g]	8345	3149
Cotton	7.97	2.59	33750[h]	26899	8741
Rubber	0.50	—	20000[i]	1000	—
Groundnut	7.97	1.66	33750[j]	26899	5603
Flowers	0.08	0.08	34367[k]	275	275
Total	51.42	21.27	—	183508	76434

Notes : * - refers to both irrigated and unirrigated area; ** - refers to irrigated area only; a - cost of vegetable crop; b - space between biwall 1.86m; c - average cost of tomato, chilli and brinjal; d - average cost of banana, grapes, papaya with the space 3m x 3m; e - cost of betelvine; f - cost of vegetable crop; g - cost of sugarcane; h - spacing 1.3m x 1.3m; i - cost of coconut; j - cost of cotton; k - average cost of rose.

Sources : Estimated from FAI (1998); NHB (1998); GOI (1996); INCID (1994).

"Core potential" refers to all those areas and crops that are not only suitable for DMI but under cultivation at present. The important crops that are suitable for DMI are sugarcane, vegetables, fruits, tea, coffee, tobacco, rubber, condiments and spices, groundnut and other oilseed crops, flowers, cotton, etc. In India, these crops together accounted for about 51.42 million hectares during the year 1994-95. However, it is not possible to bring all the areas of "core potential" under DMI immediately as over 58 percent of the "core potential" cropped area is under rain-fed cultivation. That is, out of the "core potential" area of 51.42 mha, only about 21.27 mha of cropped area is cultivated under irrigated condition at present. Therefore, it is prudent to treat the irrigated-cropped area of about 21.17 mha as the "net potential" area of DMI (Table 7.2).[24]

7.3 Capital Requirements for Utilising the Potential Area

After having understood the potential area, an attempt is also made to estimate the total capital cost that is required for utilising the potential area. As mentioned earlier, the requirement of capital cost for DMI varies from crop to crop depending upon the nature of crops, requirement of water, slope of the land, space between the plants/crops and the quality of materials used for the system. Estimates provided in INCID (1994) report show that the per hectare capital cost is relatively higher for narrow spaced crops (vegetable crops, groundnut, sugarcane, etc) when compared to wide spaced crops (fruit crops, coconut, etc). Since DMI supplies water at the root zone of the crops and the number of plants per hectare are higher in narrow spaced crops, the requirements of drip accessories such as main pipes and sub-lets, laterals, drippers/emitters, valves, etc. are higher for narrow spaced crops.

There are some difficulties in estimating the total capital that is required for utilising the potential area for drip method of irrigation. First, the requirement of capital changes even for the same crop if the space followed for cultivating the crop changes. Second, the requirement of capital cost also changes depending upon the materials (quality) used by the farmers. Third, the terrain condition and slope of the land also determine the capital requirement of the system. In view of these, we have considered the maximum per

24. It is to be noted here that the "net" and "core" potential areas for drip method of irrigation are expected to change depending upon the land use pattern, crop pattern, irrigated area and the level of groundwater exploitation. Given the over exploitation of groundwater in different parts of the country, the estimated potential area for drip method of irrigation might increase in future.

hectare capital cost required for each crop/crop group in order to estimate the total requirement for capital. In order to arrive at the total requirement of capital, we have multiplied the area of each crop with per hectare capital requirement of that crop. Table 7.2 presents the total requirement of capital separately for "core potential" and "net potential" area of DMI. According to our estimate, the total requirement for capital comes to about Rs. 1,83,508 crore for utilising the "core potential" area of 51.42 mha and about Rs. 76,434 crore for utilising the "net potential" area of 21.27 mha. That is, the requirement for capital per hectare comes to about Rs. 35,688 for "net potential" and about Rs. 35,935 for "core potential". This is considered to be much less when compared to the investment required to create one hectare of irrigation under major and medium irrigation (MMI) sector in India in the recent years (Narayanamoorthy, 1995; Gulati, Svendson & Chowdhury, 1994).[25]

7.4 Potential Water Saving by Drip Method of Irrigation

Having estimated the potential area and the total requirement of capital for utilising the potential, we have tried to estimate the potential water saving and the additional irrigated area possible from the saving of water for the country as a whole. In estimating the potential water saving, only the "net potential" (those suitable crops which are cultivated presently under irrigated condition) area of DMI is considered. Though we have tried to estimate total water saving for each crop, it was not be possible mainly due to non-availability of precise estimates of actual water consumption for certain crops. Therefore, the total water saving is estimated for certain groups of crops as well as for some individual crops. In estimating the water saving for crop groups, the average water consumption of certain important crops from the same crop groups is considered. The actual consumption of water per hectare under FMI and DMI for different crops is compiled from the report of INCID (1994). Table 7.3 presents the estimated total potential water saving and the additional irrigated area possible from the saving of water for different crops/ crop groups.

25. An estimate shows that the investment required (in current prices) to create one hectare of irrigation in major and medium irrigation sector was Rs. 237729 in 2001-02 (CWC, 1998).

Table 7.3 : Estimate of Potential Water Saving and Additional Irrigated Area by Drip Irrigation : India

Crop's Name	Net Potential Area (mha) (1994-95)	Water Use Per Hectare (mm)		Total Water Demand for Net Potential Area (million ha. meters)		Total Water saving over FMI (million ha. meters)	Additional Irrigated Area Possible million hectares)	
		FMI	DMI	FMI	DMI		By FMI	By DMI
Oilseeds[1]	5.17	500	300	2.585	1.551	1.034	2.07	3.45
Sugarcane	4.23	2150	940	9.094	3.976	5.118	2.38	5.45
Vegetables[2]	5.34	667	326	3.561	1.740	1.820	2.73	5.59
Fruits[3]	1.20	1318	629	1.581	0.754	0.826	0.63	1.31
Condiments & Spices[4]	1.00	1097	417	1.097	0.417	0.680	0.62	1.63
Cotton	2.59	856	302	2.217	0.782	1.434	1.68	4.75
Groundnut	1.66	500	300	0.830	0.498	0.332	0.66	1.11
Flowers[2]	0.08	667	326	0.053	0.026	0.027	0.04	0.08
Total	21.27	—	—	21.018	9.744	11.271	11.22	24.12

Notes : 1. Water use of groundnut is considered for estimate. 2. Average water use of brinjal, onion and tomato is considered for estimate. 3. Average water use of banana, grapes and mosambi is considered for estimate. 4. Water use of chilli is considered for estimate.

Sources : Estimated from INCID (1994); FAI (1998); GOI (1996).

As expected, the total quantum of water saved is relatively higher for water-intensive crops like sugarcane and vegetables. Though the potential area of sugarcane (4.23 mha) is relatively less when compared to the area of vegetable crops (5.34 mha), the total amount of water saved is much higher from sugarcane crop because of its heavy water consumption under FMI. According to our estimate, about 11.271 million-hectare meters of water can be saved altogether by bringing the whole "net potential" area of DMI under utilisation. The additional irrigated area possible from the saving of water as per our estimate comes to about 11.22 mha under FMI or about 24.12 mha under DMI. This means that without constructing any new irrigation dams, it is possible to create about 11 to 24 mha of irrigated area only by changing the method of irrigation from FMI to DMI. Besides this, the increase in productivity and production of different crops will also be enormous as DMI has the capacity to increase the productivity of crops by reducing the moisture stress for crops. All these clearly show that DMI is an effective technology for the sustainable use of irrigation water.

Chapter 8

Major Findings and Policy Recommendations

8.1 Introduction

Irrigation plays an important role in increasing the use of yield increasing inputs, cropping intensity and productivity of crops. However, owing to various reasons, not only the available water for irrigation purpose has been declining rapidly but the demand for irrigation water has been growing at a faster rate. In such scarce condition, efficient use of irrigation water is an importance means to increase the benefits of irrigation. It is understood that the flood method of irrigation widely practiced in India directly leads to inefficient use of water owing to enormous losses in evaporation and distribution. Since efficient use of water is important for the sustainable agricultural development, different measures have been introduced to conserve water as well as to improve the efficiency in the use of irrigation water. Unfortunately, the measures introduced for increasing the water use efficiency could not bring any impressive change so far.

Unlike flood method of irrigation, the water use efficiency is extremely high in drip method of irrigation. Since drip irrigation technology supplies water directly at the root zone of the crops through a network of pipes, it substantially reduces the evaporation, conveyance and distribution losses of water and thus, the efficiency of water use is very high. Available results in this regard show that water saving under drip method of irrigation ranges from 40 to 100 percent (depending upon the crop) when compared to flood method of irrigation. Results from research stations located in various part of India have shown that drip irrigation increases crop yield significantly and that too with reduced cost of cultivation when compared to flood method of irrigation. Some of the field level studies carried out in horticultural crops do confirm that drip method of irrigation reduces the cost of cultivation and significantly increases water use efficiency as well as productivity. Besides water saving and productivity gains, drip irrigation has quite a number of other advantages.

Despite enormous advantages from drip method of irrigation, not many comprehensive studies are available using field level data focusing on different crops. Most of the available studies in this respect have been carried out using the data supplied by the experimental research stations or relied on the experience of one or few farmers adopting drip method of irrigation. It is obvious that the experimental data may not completely reflect the farm level position as the environmental conditions under which crops are grown are totally different between the two situations. Keeping in view the limitations of the studied based on experimental data, in this study, an attempt is made to investigate the impact of drip method of irrigation on different parameters of crops using both experimental and field level data.

8.2 Major Findings of the Study

1. Due to various promotional schemes introduced by the Government of India and States like Maharashtra, the area under drip method of irrigation has increased from 1500 ha in 1985-86 to 70589 ha in 1991-92 and further to 4.50 lakh hectares at the end of March 2003. Though drip method of irrigation has been in operation over the last two decades, it is essentially considered as a scheme of government. As of 1997-98, area under DMI other than government schemes (without subsidy) accounted for only about 18 percent of India's total drip irrigated area.

2. Over the last ten years, a significant growth has been achieved in area under drip method of irrigation in absolute term in many States. However, drip irrigated area constitutes a very meagre percentage in relation to gross irrigated area in all the states in India. During 2000-01, the share of drip-irrigated area to gross irrigated area was just 0.48 percent and about 1.09 percent in relation to total groundwater irrigated area of the country.

3. State-wise area under drip method of irrigation pertaining to three time points namely 1991-92, 1997-98 and 2000-01 shows a substantial improvement in the adoption of this new irrigation technology across the states. However, the development of drip method of irrigation is not uniform across different states. In all the three time points, Maharashtra state alone accounted for nearly 50 percent of the India's total drip irrigated area followed by Karnataka, Tamil Nadu and Andhra Pradesh. There are many reasons for the rapid development of drip irrigation in Maharashtra. First, state government is very keen in promoting drip irrigation on a large scale by providing subsidy, technical and extension services to the farmers. Maharashtra government

has been providing subsidy since 1986-87 onwards through state schemes. Second, area under irrigation from both surface and groundwater is quite low and hence, many farmers have adopted drip method of irrigation to avoid water scarcity largely in divisions like Nashik, Pune, etc. Third, owing to continuous depletion of groundwater, farmers were not able to cultivate wide spaced and more lucrative crops like grapes, banana, pomegranate, orange, mango, etc., using surface method of irrigation in many regions. As a result, farmers had to adopt drip irrigation as these crops are most suitable for drip method of irrigation. Importantly, the farmers who adopted drip irrigation initially for certain crops have realised the importance of drip irrigation in increasing the water saving and productivity of crops. This has further induced many farmers to adopt drip method in some of the regions in Maharashtra.

4. Water saving and improved water use efficiency are the two important advantages of drip method of irrigation. According to the experimental data from different research stations located in India, water saving due to drip method of irrigation varies from 12 to 84 percent over the conventional method of irrigation in vegetable crops. In fruit crops, water saving varies from 45 to 81 percent. In sugarcane, which is a water-intensive crop, water saving is estimated to be over 65 percent due to drip method of irrigation (summary results of the study are presented in Table 8.1).

5. The results of field level data pertaining to three crops namely sugarcane, banana and grapes are somewhat different from the experimental results. 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. However, 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.

6. Water consumption (in quantity) per hectare is much less under drip method of irrigation as compared to flood method of irrigation in all the three crops. 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.

7. Additional area can also be brought under irrigation from the saving of water realised through the adoption of drip method of irrigation. The additional irrigated area possible from the saving of water is estimated to be 0.80 (1.98 acres) in sugarcane, 0.60 ha (1.48 acres) in grapes and 0.41 ha (1.01 acres) in banana.

8. Water use efficiency (i.e., water consumed to produce one unit of crop output) is also significantly higher in drip-irrigated crops when compared to the same crops cultivated under non-drip irrigated condition. 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. In 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 of water under non-drip irrigated condition.

9. Saving in electrical energy use (for lifting water from wells) is one of the important advantages of drip method of irrigation. While the researchers have not estimated the saving of electricity using experimental data, we have estimated electricity consumption using the field level data for both the drip and the non-drip irrigated crops. Consumption of electricity per hectare is quite low for drip-irrigated crops when compared to the same crops cultivated with flood method of irrigation. Farmers cultivating sugarcane under drip method of irrigation could save about 1059 kwh of electricity per hectare as compared to those farmers cultivating the same crop under flood method of irrigation. Similarly, while the farmers cultivating grapes could save about 1476 kwh/ha due to DMI, the same is estimated to be about 2434 kwh/ha in banana over the farmers who have cultivated these crops under FMI.

10. Efficiency in electricity use, which is measured in terms of requirement of electricity to produce one unit of output, is also significantly less under drip method of irrigation in all three crops considered for the analysis. 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.

Table 8.1 : Summary Results of Drip Method of Irrigation : Field Survey

Particulars	Crop's Name	Method of Irrigation		Benefit over FMI	
		DMI	FMI	In percent	In value
Water Consumption (HP/hours/ha)	Banana	7884.70	11130.30	29.20	3245.60
	Grapes	3310.40	5278.40	37.30	1968.00
	Sugarcane	1767.00	3179.98	44.43	1412.98
Productivity (quintal/ha)	Banana	679.50	526.35	29.10	153.20
	Grapes	243.25	204.29	19.10	38.96
	Sugarcane	1383.60	1124.40	23.05	259.20
Electricity Consumption (Kwh/ha)	Banana	5913.33	8347.75	29.16	2434.42
	Grapes	2482.77	3958.78	37.28	1476.01
	Sugarcane	1325.25	2384.99	44.43	1059.74
Water Use Efficiency (HP hours/quintal)	Banana	11.60	21.10	45.10	9.50
	Grapes	13.60	25.80	47.30	12.20
	Sugarcane	1.28	2.83	5.48	1.55
Cost of Cultivation (Rs/ha)	Banana	51437	52740	2.50	1303
	Grapes	134506	147915	9.10	13409
	Sugarcane	41993	48540	13.49	6547
Gross Income (Rs/ha)	Banana	134044	102935	30.22	31109
	Grapes	247817	211038	17.40	36779
	Sugarcane	106366	85488	24.00	20878
Capital Cost of Drip-set (Rs/ha)(without subsidy)	Banana	33595	—	—	—
	Grapes	32721			
	Sugarcane	52811	—	—	—
Net Present Worth (Rs/ha)* (without subsidy)	Banana	241753	—	—	—
	Grapes	540240			
	Sugarcane	169896	—	—	—
Benefit-Cost Ratio*) (without subsidy	Banana	2.288	—	—	—
	Sugarcane	1.909			
	Grapes	1.767	—	—	—

Notes : Banana and grapes data relate to the year 1993-94 and sugarcane data relate to the year 1998-99; * - 15 percent of discount rate is considered for computing benefit cost ratio.

Source: Computed using Narayanamoorthy (1996; 1997 and 2001).

11. Electricity saving from drip method of irrigation also helps the farmers to reduce electricity bill to be paid. Our estimate based on the current average cost of electricity supply in Maharashtra (Rs. 3.26/kwh) shows that, on an average, about Rs. 3454/ha can be saved on electricity bill alone by cultivating sugarcane

crop under drip method of irrigation. Similarly, farmers cultivating grapes and banana under DMI can also save Rs. 4811 and Rs. 7934/ha respectively on account of electricity cost.

12. Besides water and electricity saving, reduction in cost of cultivation and improvement in productivity are the two other advantages of drip method of irrigation. Since the cost of cultivation details for different crops cultivated under DMI are not available from experimental data, the study utilised only the field level data pertaining to three above-mentioned crops. Cost of cultivation (cost A_2) per hectare of the adopters is found to be relatively less when compared to the non-adopters of drip irrigation in all three crops. The cost saving in sugarcane crop due to DMI is nearly 14 percent (in absolute term Rs. 6550/ha). Farmers who cultivated grapes and banana under DMI have incurred relatively lower cost of cultivation. In case of banana, drip irrigation reduces the total cost of cultivation by about Rs. 1300/ha (2.47 percent) as compared to the farmers who cultivated the same crop under flood method of irrigation. In case of grapes, cost saving due to DMI is found to be Rs. 13408/ha (about 9 percent). Though the reduction in cost of cultivation in terms of percentage is relatively less, cost saving is found to be very high in operations like irrigation, weeding and interculture, furrows and bunding and fertilisers.

13. Productivity of crops cultivated under drip method of irrigation is significantly higher than the same crops cultivated under flood method of irrigation. Experimental data show that productivity increase due to DMI is over 40 percent in vegetable crops such as bottle gourd, potato, onion, tomato and chillies. Productivity increase due to DMI is noticed over 70 percent in many fruit crops. In sugarcane, the productivity gain is estimated to be over 33 percent. Similar kind of productivity gains is also noticed in different crops cultivated under experimental condition.

14. Similar to experimental results, considerable amount of productivity gain is also noted from the analysis of farm level data. The productivity difference in absolute term between the adopters and the non-adopters of drip method of irrigation comes to nearly 259 quintals per hectare for sugarcane, i.e., productivity of sugarcane cultivated under drip method of irrigation is higher by about 23 percent. In case of grapes, the

productivity difference between DMI and FMI irrigated crops comes to about 19 percent (about 39 quintals) and the same comes to 29 percent (about 153 quintals) in case of banana crop. In spite of incurring higher cost on yield increasing inputs, productivity of crops cultivated under FMI is significantly lower than that of DMI. There are three main reasons for higher yield in drip-irrigated crops. First, because of less moisture stress, the growth of crop was good which ultimately helped to increase the productivity of crops. Second, unlike surface method of irrigation, drip does not encourage any growth of weed especially in the non-crop zone. Weeds consume considerable amount of yield increasing inputs and reduce the yield of crops in surface method of irrigation. Third, unlike surface method of irrigation, fertiliser losses occurring through evaporation and leaching along with water are less under drip method of irrigation as it supplies water only for crop and not for the land.

15. Cost efficiency (i.e., cost incurred to produce one unit of output) is also found to be significantly higher for the drip adopters when compared to the non-drip adopters in all three crops. The non-drip adopters have incurred nearly three rupees over the adopters of drip method of irrigation to produce every quintal of sugarcane. In grapes, the non-adopters have incurred over Rs. 171 per quintal of output over the adopters. In banana, the non-adopters have incurred nearly Rs. 30 to produce one quintal of output over the counterpart. This higher cost efficiency is possible mainly because of significant increase in productivity of crops due to drip method of irrigation.

16. The undiscounted profit per hectare (gross income minus cost A_2) of the drip adopters is significantly higher than that of the non-drip adopters in all three crops analysed utilising field level data. Profit of the adopters in sugarcane is Rs. 27424/ha higher than that of the non-drip adopters. In grapes, the profit level of the drip adopters is Rs. 50187/ha higher than that of the non-adopters and for banana, the same is about Rs. 32400/ha. The study also noted that the huge profit from drip irrigation is not because of price effect, but only due to the yield effect in all the three crops.

17. The capital cost required for installing drip investment for different crops has been increasing over the years due to increase in the cost of materials used for manufacturing drip

system. The capital cost of drip system largely depends upon the type of crop (narrow or wide spaced crops), spacing followed for cultivating crops, proximity to water source (distance between the field and source of water) and the materials used for the system. Wide spaced crops generally require less capital when compared to the crops with narrow space, as the latter crops would require more laterals and drippers per hectare. Data available in INCID (1994) report shows that the requirement of capital cost is much higher for banana (Rs. 33765/ha) as compared to the same required for mango (Rs. 11053/ha), which is a wide spaced crop.

18. Field level data pertaining to sugarcane, banana and grapes also shows a wide variation in the requirement of capital cost needed for drip irrigation system. While the capital cost without subsidy comes to Rs. 52811/ha for sugarcane, the same comes to Rs. 32721/ha for grapes and Rs. 33595/ha for banana. The average capital subsidy comes to Rs. 19263/ha for sugarcane, Rs. 11359/ha for grapes and Rs. 12620/ha for banana. As a proportion of the total capital cost of drip set, subsidy amount accounts for about 35 to 37 percent, which is within a limit of provision made by the Government of Maharashtra.

19. As regards Benefit-Cost (B-C) ratio, the results available from INCID (1994) show that investment in drip method of irrigation is economically viable, even if it is estimated without taking into account subsidy given to farmers. The B-C ratio estimated excluding water saving varies from 1.31 in sugarcane to 13.35 in grapes. The B-C ratio increases significantly further, when it is estimated after including water saving. Sivanappan (1995) also estimated B-C ratio for different crops cultivated under DMI using data pertaining to the year 1993. It also indicates that the investment in drip irrigation is economically viable, as B-C ratio estimated for different crops comes to more than one. While the B-C ratio for pomegranate is estimated to be 5.16, the same is estimated to be 1.83 for cotton, which is a less-water intensive as well as a narrow spaced crop. However, it was not clear whether the B-C ratio available from the studies of INCID and Sivanappan is estimated using discounted cash flow technique.

20. The economic viability of drip investment is also studied using discounted cash flow technique under with and without subsidy conditions, using field level data pertaining to three crops.

Different discount rates considered for analysis are 10, 12 and 15 percent. The estimated results show that the Net Present Worth (NPW) of the investment with subsidy is marginally higher than that under 'no subsidy' option in all three crops. The year-wise calculation of NPW also shows that drip adopters can realise the whole capital cost of drip-set from the profit of the very first year itself.

21. Under different discount rates, the benefit-cost ratio (BCR) is computed to know whether the drip investment for three crops is economically viable or otherwise. The estimated benefit-cost ratio is much higher than one under different discount rates even without subsidy. While the B-C ratio in sugarcane varies from 1.909 to 2.095 under without subsidy condition, the same varies from 2.098 to 2.289 under with subsidy condition. In case of banana, the B-C ratio varies from 2.228 to 2.253 under without subsidy condition and 2.343 to 2.361 under with subsidy condition. Similarly, in grapes, the B-C ratio without subsidy varies from 1.767 to 1.778 and from 1.795 to 1.802 with subsidy. The higher BCR under subsidy condition suggests the positive role that subsidy plays in improving the economic viability of drip method of irrigation.

22. India has enormous potential for drip method of irrigation. Our attempt made in this study to estimate the potential and prospects for drip method of irrigation shows that while "core potential" (suitable crops that are cultivated under irrigated and non-irrigated conditions) comes to 51.42 mha, the "net potential" (suitable crops that are cultivated only under irrigated conditions) comes to 21.27 mha for the country as a whole. The requirement for capital to utilise the "core" and "net potential" areas is estimated to be about Rs. 183508 crore and Rs. 76434 crore respectively. That is, the requirement of capital per hectare comes to about Rs. 35688 for "net potential" and Rs. 35935 for "core potential". By utilising the "net potential" area of DMI, an amount of about 11.271 million-hectare meter of water can be saved. The additional irrigated area possible from the saving of water is estimated to be 11.22 mha under FMI or about 24.12 mha under DMI.

8.3 Policy Recommendations

The findings of the study clearly demonstrate that micro irrigation has a macro future in India. Drip method of irrigation reduces cost of cultivation, weed problems, soil erosion and increases water use efficiency as well as electricity use efficiency, besides performing as an useful devise in reducing the over-exploitation of groundwater. However, despite providing substantial amount of subsidy, the spread and coverage of drip irrigation in India is not very encouraging as of today due to various reasons. We have listed below some policy recommendations, which may be useful for expanding the adoption of drip method of irrigation in India.

1. It is understood from our field study that capital cost required to install drip irrigation is relatively high. Because of this reason, considerable percentage of farmers have expressed that they are unable to adopt this technology for low value crops. If drip system is made available with low cost, area under drip irrigation can be increased at a faster rate. Therefore, measures can primarily be taken to reduce the fixed cost of drip irrigation by promoting research and development activities. By recognizing drip industry as an infrastructure industry as well as announcing tax holiday for specific time periods to all those drip set industries which produce genuine drip materials, the competition can be increased that will ultimately bring down the cost of the system. Some companies have come out with low cost drip irrigation system which can be adopted even by the farmers having less than one acre of land. Studies need to be carried out to find out the feasibility of low cost drip materials including its environment feasibility using field level data.

2. The centrally sponsored scheme of drip irrigation does not provide subsidy for sugarcane crop. The logic behind this is not clearly known. Since it is an important and also a heavy water-consuming crop, this restriction should be removed to increase the drip irrigated area at a faster rate. This would also ultimately help to reduce the water crisis faced by various States to some extent.

3. The rate of subsidy provided through government schemes is fixed uniformly for both water-intensive as well as less water-intensive crops. This needs to be restructured. Special subsidy programme may be introduced for water-intensive crops like sugarcane, banana, vegetables, etc. Differential subsidy rates can be fixed based on the types of crops and the rate of consumption of water. Uniform level of subsidy schemes currently followed for water-scarce and water-abundant areas

need to be changed and higher subsidy should be provided for those regions where the scarcity of water is acute.

4. Though there was no delay in sanctioning subsidy, Maharashtra State's experience indicates that farmers have to wait at least six months to receive the amount of subsidy from the concerned department. This increases farmers' debt burden as majority of the farmers use bank loan for installing drip system in their field. In order to encourage the adoption of drip technology, adequate arrangements should be made to distribute the amount of subsidy within one or two months.

5. Sugar industries always try to increase the area under sugarcane to increase their capacity utilisation in almost all the States in India. They are least bothered about the method of cultivation of sugarcane. Since sugar industries have close contact with sugarcane cultivators, some kind of target may be fixed for each sugar industry to bring cultivation of sugarcane under drip method of irrigation. Apart from saving of water, this would also help to achieve cultivation of sugarcane in sustainable manner. Despite irrigation water shortage in many States, not only does the area under sugarcane continue to grow at a relatively faster rate, but it is cultivated predominantly under flood method of irrigation. This puts additional pressure on water resources. In order to avoid huge demand-supply gap in irrigation water in future, concerted policies should be formulated to bring all possible areas of sugarcane under drip method of irrigation.

6. Farmers have inadequate knowledge regarding the usefulness of liquid fertilisers. Though a few farmers in our field study have used liquid fertilisers along with water, most of the farmers are afraid to use liquid fertilisers through drip pipe network. They feel using liquid fertilisers through water may lead to system clogging. This fear of the farmers should be removed by introducing regular and frequent demonstration. Importance of liquid fertilisers in increasing input efficiency and reducing the cost of cultivation should be clearly demonstrated to the farmers by the extension officials.

7. Inadequate information about the operation, maintenance and usefulness of drip irrigation is one of the main reasons for its uneven spread across regions in India. Farmers still do not have full knowledge regarding the usefulness of drip irrigation.

Even the adopters do not know fully how much of subsidy is available per hectare for different crops. Owing to poor exposure, farmers are reluctant to invest such huge money on drip irrigation. In fact, many farmers do not know the fact that drip irrigation can also be used efficiently and economically for crops like sugarcane, cotton, vegetables, etc. Giving wide publicity and strengthening the existing extension services can remove these problems. The extension network currently operated mainly by government agencies does not seem to be making significant impact on the adoption of this technology. Therefore, there is a need to revamp the whole extension network by involving the drip set manufactures in order to increase the quality of extension service.

8. Drip sets manufacturers should be asked to involve intensively in promoting drip irrigation by introducing frequent demonstration at farmers' field. Since the use of drip method of irrigation is still in the take-off stage in India, active role of drip manufacturers' is essential in promoting drip irrigation as well as developing confidence among the farmers about the usefulness of this new technology.

9. For a speedy growth of drip irrigation, a special package scheme can be introduced where priority can be given in providing bank loan for digging wells and electricity connection (pump-set) for those farmers who are ready to adopt drip method of irrigation for cultivating any crop.

10. Groundwater is the only source of water being used for drip method of irrigation in India. Unlike other countries, water from surface sources (dams, reservoirs, etc) is not used for drip method of irrigation. Since water use efficiency under surface sources is very low owing to heavy losses through conveyance and distribution, farmers should be encouraged to use water from surface sources for drip method of irrigation. This can be done by allocating certain proportion of water from each irrigation projects only for the use of micro irrigation.

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

12. Though drip irrigation has been in use in different States since mid-eighties, Statewise potential area is not estimated as of today. Therefore, it is essential to prepare State-wise and crop-wise potential area for DMI. A detailed estimate on State-wise potential would be useful to fix the target to be achieved and also for formulating schemes for promoting drip method of irrigation.

13. Except in Maharashtra and Andhra Pradesh, no other state has separate state sponsored schemes for promoting drip irrigation as of today. All other states have been operating schemes mainly with the support of Central government (which is known as centrally sponsored schemes), which started in 1990-91. Considering the water shortage, it is essential to have separate State sponsored schemes in each state by following the experience of Maharashtra state.

8.4 Concluding Remarks

There is a feeling among some quarter of policy makers and researchers that the adoption of drip method of irrigation cannot be increased without providing subsidy because of its capital-intensive nature. It is true that drip irrigation is a capital-intensive technology, but it does not mean that its adoption of cannot be increased without subsidy. Subsidy can be a necessary condition for encouraging the adoption of drip method of irrigation but cannot be a sufficient condition for sustaining the growth of it, as many other factors determine the adoption of the same. Studies carried out using field level data from Maharashtra on three crops clearly show that the investment on drip irrigation is economically viable even without government subsidy. The estimated benefit-cost (BC) ratio varies from 1.73 to 2.23 among the three crops under without subsidy condition. Even though subsidy is not needed to enhance the economic viability of the drip system, it is still needed to enhance the incentive for the widespread adoption of DMI particularly among the resource poor farmers (marginal and small categories). Subsidy can be phased out eventually once the new irrigation technology covered an adequate enough to expand subsequently through the demonstration effect.

The most important task standing before the policy makers is to find out the ways and means to convince the farmers about the economic and social feasibility of drip method of irrigation. Since it involves relatively higher amount of investment, farmers often ask the questions such as what will be the payback period? Whether investment will be viable? How much will be the water saving? and What will be the productivity gains? It appears that these questions arise mainly because of poor exposure about the social and economic advantages of drip technology. Therefore, efforts are needed to convince the farmers through quality extension network, as India's highly successful green revolution was also the result of extension innovations as much as technology. As the available water for irrigation purpose has been declining drastically, we need to act quickly in adopting water saving technologies otherwise we may end with severe water scarcity before the year of 2020, as indicated by macro-level estimates.

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