SUSTAINABLE AGRICULTURAL DEVELOPMENT AND MICRO-IRRIGATION

A Narayanamoorthy* and R S Deshpande**

Abstract

Efficiency in resource use is one of the important pre-requisites for sustainable agricultural development. Among various factors the type of technology, process of commercialisation and the inadequate extension services have together contributed towards the inefficiency in resource use. Economic use of irrigation water is one of the important components in achieving optimum resource mix and thereby sustainable development. Due to the extensive cultivation of crops under the conventional method of irrigation (flood irrigation under canal/well), the inefficiency in use of water has been increasing. The negative externalities generated out of the over-use of water are enormous. Water logging, soil salinity, soil erosion and formation of salt layer on the top crust of the soil have been referred to as important externalities. This has also affected the total availability of water and degraded the soils. The gap between availability and requirement of water arises mainly out such inefficient use. Keeping in view the growing needs of irrigation water and the rapid decline in the available potential of irrigation water, different measures have been introduced to improve the efficiency in water use. The measures (technological as well as economic alternatives) introduced so far could not bring any appreciable change in the existing pattern of water use. However, the new water conservation technologies, namely, drip and sprinkler methods of irrigation introduced recently have proved to be efficient in terms of water use and increasing the productivity of crops. Drip method of irrigation has a wider acceptance and the area cultivated under this method has been increasing. In India, we do not have many studies analysing the impact of drip irrigation on environmental parameters. The paper addresses to the issues like how much water is being saved by using this technique or what is the incremental productivity or the viability of the investment from the field perspective. In addition to this the environmental impact questions assume greater importance. The present study clearly brings out the water saving in field conditions under drip irrigation and thus helps to estimate the positive externality of this technique. It also brings out the environmental externalities of drip irrigation in the horticultural cropping systems. The study suggests that drip irrigation has a positive contribution towards maintaining the environmental sustenance.

* Lecturer, Gokhale Institute of Politics and Economics, Pune.

** Professor and Head ADRT unit Institute for Social and Economic Change, Bangalore.

SUSTAINABLE AGRICULTURAL DEVELOPMENT AND MICRO-IRRIGATION

A Narayanamoorthy[*] and R S Deshpande[**]

I. Introduction:

In the context of liberalisation the responsibility of sharing the growth as well as sustaining the food security are the two major responsibilities of the agricultural sector. Apart from participation in the sustenance of overall growth, the agricultural sector has also to accord prime importance to the sustainability in resource use. It has been well documented that the use rates of resources especially in agricultural sector have not been monitored continuously during the process of the technological change. Even though the policy framework of agricultural sector as well as resource sector have underscored the efficiency in resource use the factors like quality of technology, process of commercialisation, inadequacy of information and institutions have all together contributed towards the current level of inefficiency in resource use. This has given rise to a large number of environmental problems in Indian agriculture. The major factor identified as instrumental for most of these problems in the agricultural sector is irrigation. During mid sixties the technological change in Indian agriculture necessitated the provision of irrigation to optimize the use of new technology. Incidentally, the major irrigation schemes (surface irrigation) received the bulk of the investible funds both because of its high capital intensity as well as the speed needed to cover large irrigated areas. In India we have utilized substantial amount of surface irrigation potential across the country and the environmental problems have been highlighted by many researchers (Bhatia 1992, Shah 1993, Vaidyanathan 1994, Saleth 1996 and Paranjapye 1995). According to a conservative estimate by Central Water Commission (CWC) about 141 Million Hectares out of the total geographical area is subjected to various kinds of erosions. The CWC has also recorded that about 40 per cent of the area has waterlogged

[*] Lecturer, Gokhale Institute of Politics and Economics, Pune.

[**] Professor and Head ADRT unit Institute for Social and Economic Change, Bangalore.

at various degrees. The negative externalities of over use of water are enormous and emerge as water logging, soil salinity, soil erosion, as well as formation of salt layer on the top of the soil crust. The story is not very different in the groundwater irrigated areas. The flood method of irrigation used in groundwater irrigated areas has caused similar problems, though to a smaller extent, in addition to the fast depletion of groundwater table in a number of blocks in the country. In the absence of well formulated recharge policy for groundwater, this may also create significant irritation in the environmental sector. These problems together have not only affected the availability of water and quality of soil as resource, in long run these may have telling effects on the yield of the crops and sustenance of growth too.

The flood method of irrigation is widely practiced both under ground water and surface irrigation systems in Indian agriculture. This conventional method of irrigation not only leads to inefficient use of irrigation water due to enormous losses in evaporation and distribution but also brings in many negative externalities in agriculture(Nadkarni, 1996). While the over-use of irrigation causes damage to soils in the form of water logging and salinity on the one side, it reduces the yield of crops on the other side (Chopra, 1996).. With the fast increase in the density of wells, the rate of exploitation of groundwater is increasing at an exponential rate (Bhatia, 1992; Shah, 1993; Vaidyanathan, 1994; Dhawan, 1996; Saleth, 1996). As a result of over-exploitation of water, problems like sea water intrusion, progressive lowering of water table, increase in fluoride level in groundwater, groundwater mining etc., have been noticed across the country (Vaidyanathan, 1994). Keeping in view the growing needs of irrigation water and rapid decline of available irrigation potential, many programmes/regulations have been introduced to arrest the profligate use of water both under the surface and groundwater irrigation systems. However, these programmes, introduced for improving the existing water use pattern, could not achieve anything impressively so far. Logically, the pattern of water use in the agriculture will inflict an unrecoverable cost on the sustainability of the growth in the sector. This can be pursued in three ways. Firstly, the over use of water resources are depleting the availability of water as well as the quality of soil. Therefore, in long run the growth in the resource use is likely to be limited. Secondly, the water use induces the farmers to adopt a cropping pattern oriented towards commercial crops thereby increasing the risk in the gross value of production as well as neglect of the traditional food crop oriented cropping system. Lastly, in the long run the yield rates of the crops will suffer because of the high spurting rate of the soil.

Most of the water related environmental problems are associated with the flood method of irrigation (FMI).Therefore these can be reduced by adopting a new method of irrigation as well as proper pricing of water. The newly introduced drip method of irrigation (DMI) has proved extremely effective in reducing water-related environmental problems (Narayanamoorthy, 1996; Narayanamoorthy and Deshpande, 1997). In this method water is supplied exactly to the root zone of the crops through a network of pipes with the help of emitters at regular intervals. Since water is supplied through a network of pipes, controllability of water is perfectly ensured and as a result evaporation and distribution losses are reduced to a negligible level.

Drip method of irrigation has many resource saving as well as economic advantages. Hitherto the known studies have not attempted to bring out the importance of drip method of irrigation particularly its water saving capacity, environmental impact and economic viability using field level data. It is in this context, the present study aims to focus specifically on two issues:

1. to investigate the water saving in field conditions under drip irrigation and thus to estimate the positive externality of the drip irrigation technique;
2. to map the environmental externalities of drip irrigation in the horticultural cropping systems.

This paper is organised into five sections. First section up to now was devoted to the introduction of the problem. The second section provides the material and methods utilised in this paper. The third section briefly reviews the existing water related environmental problems using macro-level data. Most important aspects of drip irrigation like water saving, productivity enhancing and benefit-cost advantages using experimental data of different research stations are discussed in the following section. The fifth section analyses water use efficiency and economic viability using the data collected from two districts of Maharashtra.

II. Material and Methods

Drip method of irrigation is a relatively new irrigation technology in Indian agriculture, many research institutions have been involved in experimenting the viability of this method for different crops especially at experimental research stations. We have collected these experimental data of different research stations on drip irrigation from the *Status Report on Drip Irrigation* published by the Indian National Committee on Irrigation and Drainage (INCID, 1994).

For the purpose of field data, we selected two districts, namely, Nashik and Jalgaon of Maharashtra state. In these districts DMI is used extensively. Our observation is based on the area and number of drip irrigators across the districts in the state. List of adopters of drip irrigation were collected from the drip irrigation cell of the Commissionorate of Agriculture, Government of Maharashtra, Pune. Since water use and productivity of crop varies from crop to crop, we selected two dominant horticultural crops one from each district for an in-depth study. The two selected crops are Banana from Jalgaon district and Grapes from Nashik district. While the adopters were selected randomly from the adopters list of 1992-93, the non-adopters were selected purposively with the help of the village accountant. In each district, 50 farmers (25 drip adopters and 25 non-drip adopters) were selected. In an impact study, it is essential to compare the farmers who cultivate crops under DMI and FMI to understand the water use efficiency and economic viability. Thus a total of 100 sample farmers were selected.

III. A Review of Water Related Environmental Problems

In India, a sizeable chunk of cultivated land has been affected by water related environmental problems. According to a rough estimate by the Central Water Commission (CWC, 1996), about 141 m.ha, out of 329 m.ha of geographical area is subject to water and wind erosion. In addition to this, about 34 m. ha is affected by land degradation problems like water logging, alkaline and acidic soils, salinity, ravines and gullies, shifting cultivation, etc. Thus only about 47 per cent of the total geographical area can be considered as unaffected land resource. The major causes for land degradation are water logging and salinity and estimates indicate that over 40 per cent of the land area has been affected by such problems. Out of 8.5 m.ha of the land affected by water logging in the country, nearly 2.46 m. ha is estimated to be caused by inadequate drainage system in the command areas (Table 1). Similarly out of 5.5 m. ha of the land affected by salinity, as much as 3.06 m.ha comprises of the area affected due to irrigation related problems. Maximum problem on 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 the water logging is the over-use of irrigation and negligence of drainage in the irrigation systems. In this connection Vaidyanathan stated that, "*injudicious use of canal water - typically arising from over-irrigation and neglect of drainage - causes water logging and a rise in the water table which if left uncorrected, eventually leads to salinisation*" (Vaidyanathan, 1996, p. 83). While discussing about groundwater problems, he mentioned that "*practically all districts of the Punjab and parts of Haryana are reported to be extracting more(groundwater) - in some cases by as much as 100 per cent - than the estimated usable discharge. The average depth of the water table is estimated to be falling by 1 to 33 cm per annum in different districts of Haryana*" (Vaidyanathan,p.48). Similarly, a study related to Gujarat indicated that in 87 out of 96 observation wells monitored by the Central Groundwater Board the water table has been declining since 1980s, the average decline for the sample districts ranges from 0.5 meters in one case to as high as 9.5 meters in the worse case (Bhatia, 1992).

Another study related to Gujarat (costal areas of Saurashtra region) showed the adverse conditions as regards to the over-exploitation of groundwater(Shah,1993). Tubewells development in this areas shifted crop pattern from food crops to sugarcane to a lager extent. As a result, 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 experienced reduction in the crop yields and found that the well water becoming brackish. Even under these conditions some farmers continued to irrigate the crops with the saline water thereby ruining their top soils. In fact, the unfettered exploitation of groundwater in this region inflicted largely irreparable damage on land resources and affected large number of families (Shah, 1993, p. 133).

Although the examples quoted above are only a few, every major state in the country has been facing these kind of problems. What is clear from the above discussion is that a large share of the cultivable area is currently facing problems like water logging, over-exploitation of groundwater and other water related problems because of the uncontrolled and over-use of irrigation. With the present method of irrigation, it is not unlikely that these problems will assume a dangerous proportion, as the controllability of irrigation is very less under conventional method of irrigation. Unlike surface method of irrigation, under drip method of irrigation these water related problems could be minimised as in this case water can be controlled .[1]

[1] According to one estimate, water management under DMI is very simple and one labour can easily manage up to

IV. Analysis Based on Experimental Station Results

Drip method of irrigation is a relatively new technique for Indian agriculture, detailed studies based on field level data are not easily available. The available studies are either based on the data of research stations or of an individual farm. Ofcourse the results of experimental stations would be useful to understand the effectiveness of this technology to some extent. But it will be necessary to understand the results of experimental station level data before going to analyse the field level data. The comparative results of DMI and FMI with regard to water use efficiency and productivity gains are presented in Table 2. It is clear from the table that DMI saves enormous amount of water compared to the flood method of irrigation in almost all the crops reported in the table. Water saving varies from 30 per cent for Tomato to over 80 per cent in the case of Lady's Finger. Saving of water is in the range of 48 to 77 per cent among the water intensive crops like Grapes, Sugarcane and Banana. It clearly indicates the importance of drip method of irrigation in reducing the consumption of water. Besides water saving, productivity of crops is also significantly higher under DMI over FMI. Three important environmental fall-outs are clearly indicated by the data. Firstly, the effect of limited water use helps in economising not only water as a resource but also saves electricity. Secondly, as the quantum of water used per unit of area is reduced drastically, it does not allow any water logging and the depletion of groundwater. Lastly, the speed with which water flows in the FMI, it causes spurting of the soil, by reducing the direct impact on the soil the spurting of the soil particles gets reduced significantly. This in long run helps to maintain the soil health and fertility.

In order to understand the economic aspects of any technology, one has to compare the investment with the total gain of the project. As drip method supplies water for crops through a network of pipes, it requires a considerable amount of initial investment to irrigate every hectare of land. Therefore, farmers consider this as a capital intensive technology. Capital cost of drip system varies depending upon the nature of crops and space. Narrow spaced crops require relatively more capital cost than the wide spaced crops as the wide spaced crops require more emitters as well as sub-system and main pipes (INCID, 1994). Estimates show that capital cost of the wide spaced crops like Coconut, Mango and Orange varies from about Rs. 11000/ha to Rs. 20000/ha, while the capital cost for narrow spaced crops is in the range of about Rs. 23000/ha. in

---

10 ha of land (INCID, 1994).

Grapes to Rs. 33000/ha. for Banana. Although the initial requirement of capital cost is more for DMI, it is not very exorbitant when compared to the requirement of investment for creating one hectare of irrigation under major and medium irrigation sector in India.[2]

The economic viability of a technology which involves fixed investment is tested on the benefit-cost (B-C) ratio and Net Present Worth at an acceptable discount rate. Normally, any project can be treated as economically viable, if the B-C ratio of the project is more than one. We have presented the B-C ratios for different crops cultivated under drip irrigation compiled from the publication of INCID (1994) in Table 3. The Benefit-Cost Ratio under drip irrigation is normally computed in two ways by including the benefits accrued through water saving and excluding such benefits. It is evident from Table 3 that B-C ratio is in the range of 1.31 (for Sugarcane) and 13.35 (for Grapes) when computed excluding benefits out of water saving and the same varied between 2.78 for Sugarcane to 32.32 for Grapes when such benefits are included. This means that the Drip irrigation technology is also economically viable apart from water saving and productivity gains.

V. Drip Irrigation Under Field Conditions and Environment

The experimental station level data represent a control situation. Even though our results clearly indicate that DMI has substantial advantages in terms of productivity gains and water saving over the flood method of irrigation. The environmental interface of the drip method of irrigation however comes out very clearly only under field conditions. In the actual field conditions the interaction of man with the method of irrigation is incorporated in the benefit computations. Similarly on the cost side we have to incorporate the social costs in terms of the negative externalities. Moreover, as mentioned earlier, not many studies are available relating to drip irrigation especially bringing out the water saving and productivity enhancing impact on crops under field conditions. The real environmental advantages of drip method of irrigation can be understood only by analysing farmer's field level data.

Water Saving and Resource Conservation under Drip Irrigation

Water use pattern differs widely across different modes of irrigation namely tank, canal and

---

[2] Estimates show that the investment required to create one hectare of irrigation under major and medium irrigation sector during the Seventh plan was nearly Rs. 60 thousand. For more details in this regard see, Narayanamoorthy (1995); Gulati et al., (1994).

groundwater. Control and management of irrigation are also varies substantially across these sources of irrigation (Dhawan, 1988). While tank and canal irrigation are predominantly managed by public authorities, the groundwater structures are normally owned by individual farmers. Management of irrigation ,therefore, is relatively better in groundwater irrigated areas than other sources of irrigation (Vaidyanathan, 1996). Although water management in groundwater irrigated area is relatively better than tank and canal command areas, still enormous water losses occur through evapo-transpiration and through distribution mainly because of the adoption of the flood method of irrigation. Pattern of water use under DMI is entirely different from that under the FMI, as water is supplied through networks of pipes under this method. To understand the water use pattern, we have calculated number of irrigation used per hectare and hours of water used per irrigation under DMI and FMI. It is evident from the Table 4 that the number of irrigation used per hectare are significantly higher for drip adopters as indicated by earlier study (NABARD, 1989). For instance, for Banana, the drip adopters have irrigated 78 times more than the non-drip adopters. Similarly, for Grapes, the drip adopters have applied about 82 irrigation more than the non-drip adopters. To maintain moisture level, farmers with DMI use water almost thrice a week which increases the actual number of irrigation for this group. However, this consumes less water when compared to the surface method of irrigation. For instance, on an average per hectare, farmers with DMI have used about five hours for Banana and seven hours for Grapes for each turn of irrigation in spite of using lower HP pump-sets. But the same is 16 hours for Banana and 19 hours for Grapes under FMI. Farmers have to use more time for each irrigation in the case of surface method because of the following reasons. Firstly, FMI supplies water not only for the crop zone but also the non-crop area which consumes substantial quantity of water and allows a large quantum of weeds to grow. Secondly, uneven land surface and water conveying channels also consume considerable quantity of water through seepage in the surface method of irrigation. Evaporation losses are also very high in open water conveying channels which increases the time required for using water. But these problems are completely eliminated DMI as it supplies water through pipe network (Narayanamoorthy, 1996 and 1997a).

Water Saving under DMI and FMI

Water requirement of a crop at field level is determined by various factors. Among these factors apart from the method of irrigation the type of soil, slope of the land, the water-lifting devices and the Pump-set with higher horse power (HP) usually takes less time to irrigate per unit of land compared to the pump-set having lower HP. Most of the studies based on research stations data have measured water consumption in terms of centimeters (Cm) under DMI (INCID, 1994). In practice, measuring water in terms of Cm is not an easy task at field level as HP of the pump-sets and water level of the well vary across the farmers. Because of these difficulties, we have measured water consumption in terms of HP hours of irrigation. HP hours of water consumption can be computed by multiplying the HP of the pump-set with hours used in that pump-set. Table 5 presents the quantum of water consumption and water use efficiency of drip and non-drip irrigated crops. It is evident from the table that the consumption of water by crops under DMI is significantly lower than the crops which are cultivated under FMI. Water saving in terms of HP hours is 3245.65/ha and 1968.02/ha for Banana and Grapes respectively over the method of flood irrigation. In terms of percentage, the saving of water by DMI is about 29 and 37 per cent respectively for Banana and Grapes over FMI. The implication of the lower use of water is that the exploitation of groundwater can be reduced by about 29 to 37 per cent in these two crops by adopting DMI.

Water saving also has another angle in terms of additional area which can be brought under irrigation. We have estimated the additional area that can be brought under irrigation through saving of water in both Banana and Grapes. Our results show that an additional area of 0.60 ha. (1.48 acres) in Grapes and 0.41 (1.01 acres) in Banana can be brought under irrigation by adopting DMI. This undoubtedly confirms the importance of drip irrigation in saving of water and bringing more area under irrigation. Although water consumption per hectare is much lower in DMI, one cannot straightaway come to a conclusion that water is used efficiently under DMI. Normally, the efficiency of water use is measured in terms water consumed to produce one quintal or unit of produce. In order to arrive at this, we have divided per hectare consumption of water with per hectare yield of the crop *(see, last two columns of the Table 5)*. It is clear from our computations that water use efficiency is substantially higher in drip irrigated crops. For instance, Banana under DMI consumes only 11.60 HP hours of water to one quintal of produce when compared to 21.14 HP hours under FMI. Similarly, in the case of Grapes, DMI required about 13.61 HP hours of water compared to FMI, which consumed 25.84 HP hours. This clearly shows that DMI not only reduces the per hectare consumption of water but also the requirement of water per unit of crop yield.

Electricity Saving under Drip Irrigation

Drip irrigation technology is also useful in reducing the consumption of electricity and therefore an energy efficient method of irrigation. We have noted earlier that the hours of water used per hectare under DMI are lower than FMI. Therefore it follows logically that the hours of use of the pump set and thereby the consumption of electricity also reduces significantly under DMI. In order to know the impact of drip irrigation on electricity saving, we have estimated electricity consumption based on the hours of pump-set operation for both drip and non-drip irrigated crops. For estimating the quantum of electricity saved, we have assumed that for every hour of operation, 0.75 kwh of electricity is used per HP (Shah, 1993). It is clear from the Table 6, that farmers using DMI utilise lower amount of electricity for both the crops compared to FMI. According to our estimate, the saving of electricity by DMI is about 2430 kwh/ha in Banana and 1470 kwh/ha in Grapes compared to the same crops cultivated under FMI. Further the estimate on money saved in electricity bill per ha shows that farmers who cultivate crops under FMI can save about Rs. 1217/ha in Banana and Rs. 738/ha in Grapes. This indicates that the drip irrigation technology not only helps in saving water and increasing the yield of crop but also reduces the cost of cultivation enormously by reducing the cost of electricity.

Economic Viability of Drip Irrigation Technology

Sustainability of the irrigated agriculture hinges upon two components. These include the conservation of the resources along with their economic use and the financial viability of the investment. In order to judge the economic viability of any technology one has to consider the net benefits arrived from the entire life period of that technology in terms of aggregates. If the net benefits of a particular technology at the completion of the investment is expected to be more than the cost, farmers would go for adopting such technology keeping in view the financial viability of the investment. But many times the financial viability alone cannot be a sufficient proof for the sustainability of the technology. The sustenance links mainly on the social cost as well as the indirect social benefits emerging out of the application of the technology. In the case of drip irrigation we have given both the sides of the social aspects in the table.

Social Cost Components	Social Benefits Components

↳ As the method requires bulk investment, the opportunity cost of the capital must be accounted for. ↳ The quantum of investment is accessible only to a few among the cultivators, hence the investment may lead to intra-group inequalities. ↳ The investment may induce higher adoption of commercial crops thereby dampening the growth of food crops. The crop preferences will become more specific.	↳ The technology will help in using the water and electricity more economically. Thus there will be a substantial saving on account of these two resources. ↳ Negative externalities like water logging, salination, soil spurting, weed growth are completely avoided and thereby the cost associated with these are converted into benefits. ↳ Productivity increase induces the farmers' participation in the market and thereby their responses to the policies.

In order to evaluate the economic viability of investment on drip system for the two selected crops, we have attempted to calculate Net Present Worth (NPW) and Benefit-Cost (B-C) ratio using Discounted Cash Flow (DCF) technique. As the DMI involves fixed capital, one has to calculate income stream for the entire life period of the drip set. For estimating cash in-flows and cash out-flows of drip investment we have considered the following assumptions:

(i) The life period of the drip set is considered as five years for Banana and ten years for Grapes for calculating NPW and Benefit- Cost ratio as followed by the viability analysts INCID (1994).

(ii) No change in the cost of cultivation is assumed and thus income generated by the drip irrigation during the entire life period is treated accordingly.

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

(iv) The technology which is used for crop cultivation is assumed constant for both the crops during the entire life period of the drip set.

Before getting on to the financial viability analysis of drip investment, let us know about the cost of cultivation, capital cost of drip set and amount of subsidy of the two crops cultivated under DMI. These details are given in Table 7. As expected, the gross income and profit (computed as farm business income) are significantly higher for the crops cultivated under DMI compared to the crops cultivated under FMI. Because of higher productivity and lower cost of cultivation, the profit is significantly higher for the crops cultivated under DMI. However, this profit cannot be considered as a real profit of the crops because it does not include the capital cost of the drip set, its depreciation and interest accrued on the fixed capital while calculating the net profit of the crops. The life period of the drip-set is one of the important variables which determine the per hectare profit especially in the case of fixed investment. Therefore, we have computed NPW and B-C ratio using DCF technique for the entire life period of drip set for both the crops.

Based on the assumptions mentioned earlier, we calculated NPW and B-C ratio under different discount rates for both the crops. Although all the sample farmers selected for the study have received subsidy from government schemes for installing drip irrigation system, computation has been done for both with and without subsidy conditions. This is done primarily to understand the impact of subsidy on the economic viability of investment on drip irrigation. The results of sensitivity analysis of NPW and B-C ratio are reported in Table 8 for both the crops. It is clear from the table that change in the discount rate significantly changes the value of net present worth in both the crops under both the conditions. For example, at 15 per cent discount rate, the value of NPW is Rs. 540241/ha, but it increased to Rs. 666440/ha when the discount rate falls from 15 per cent to 10 per cent under without subsidy condition. Similarly, with subsidy condition also, the NPW increased from Rs. 551220/ha to Rs. 677911/ha when discount rate falls from 15 per cent to 10 per cent in Grapes. This means that farmers will get about Rs. 5.40 lakhs/ha to Rs. 6.66 lakhs/ha in Grapes without subsidy condition and Rs. 5.51 lakhs/ha to Rs. 6.78/ha when they get subsidy for installing drip irrigation at the end of life period after deducting all costs including interest on fixed investment. Similar results are arrived in Banana as well. As expected, the influence of subsidy factor in increasing the viability of investment is very much noticed in both the crops. In both with and without subsidy conditions and also at different discount rates used for computation, the B-C ratio clearly shows that investment on drip irrigation is economically viable. Further, the calculation shows that farmers can realise their whole capital cost invested on drip system from the very first year in both Banana and Grapes. These sufficiently confirm that drip irrigation technology not only helps in reducing the over-exploitation of groundwater but also an economically viable technology.

It is essential to bring forth at this juncture the impact of the DMI on the sustainability in the context of a farming system. Essentially, micro irrigation is a resource saving technique and therefore the use-rates are controlled under a given constraint. This allows the farmer to extend the life of the well and optimise the energy use. Further by avoiding the negative externalities the farming system sustains the productivity growth. It also helps to maintain the quality of the basic land and water resources. If one includes the social aspects on the cost as well as on the benefit side as indicated above the social viability of drip irrigation will be an attractive preposition in the context of environmental sustainability.

Conclusion

Both experimental and field level results indicate that drip method of irrigation is effective in reducing water and electricity consumption.and water related environmental problems. According to the experimental data, water saving under drip technology varies from 30 to 80 per cent in different crops compared to the same crops cultivated under flood method of irrigation. Similarly, the results of field level study also show that drip technology helps saving water about 29 per cent in Banana and about 37 per cent in Grapes compared to the same crops cultivated with similar environmental condition under flood method of irrigation. The benefit-cost ratio and net present worth (NPW) computed using discounted cash flow technique for judging the economic viability of the investment on drip irrigation system also show that investment on drip system is economically viable and environmentally adaptable. Further, the computation of NPW shows that the farmers can realise the whole capital cost of drip system from the profit of very first year even without getting subsidy from government. Therefore, keeping in view the rapid decline of irrigation potential and the fast emerging water related environmental problems especially in the over exploited groundwater zones, concerted policies should be formulated for promoting drip method of irrigation.

The results of our analysis above indicate five important aspects in the context of sustainability of the agricultural sector. Firstly, micro-irrigation helps to control the use rate of water and electricity as resources thereby increasing there horizontal availability (for more number of farmers). This enhances the sustainability of resource use. Secondly, through the method of micro irrigation the negative externalities such as soil degradation due to spurting and salination. The estimation of social benefits out of the avoidance of this externality are difficult to compute but certainly very high. Thirdly, as micro irrigation irrigates only the root zone of the crop it reduces the growth of weeds significantly. The reduction of growth in weeds allows larger quantity of nutrition availability to the main crop. This helps in enhancement of productivity of the crop.

Fourthly, the improvement in productivity not only helps in boosting the growth of crop economy but help to increase savings and thereby investment. Lastly, the aggregate impact of micro-irrigation observed from both resource as well as from the production technique side indicates its positive contribution towards sustainability.

Formulae Used for the Viability Analysis

NPW =

BCR =

Where,

B_t - Benefit in each year, C_t - Cost in each year,
n - number of years, t - 1, 2, 3,... n, and
i - interest (discount) rate.

References

Bhatia, Bela. (1992), "Lush Fields and Parched Throats: Political Economy of Groundwater in Gujarat", *Economic and Political Weekly*, Vol.27, Nos. 51 & 52, December 19-26, pp. A142-A170.

Chopra, Kanchan. (1996), "The Magnitude of Degraded Land: Issues and Analysis of Technological and Institutional Solutions" *Indian Journal of Agricultural Economics*, Vol.51, Nos. 1 & 2, January-June, pp. 238-248.

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

Dhawan, B.D. (1996), *Groundwater Depletion, Land Degradation and Irrigated Agriculture in India*, Commonwealth Publishers, New Delhi.

Gittinger J, Price. (1984), *Economic Analysis of Agricultural Projects*, Second Edition, The Johns Hopkins University Press, London.

Gulati, Ashok; Mark Svendsen and Roy Chowdhury Roy (1994), "Major and Medium Irrigation Schemes: Towards Better Financial Performance", *Economic and Political Weekly*, Vol.29, No.26, June 25, pp. A72-A79.

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

Nadkarni, M.V. (1996), "Agriculture and Environment", in M.S. Rathore (ed.), *Environment and Development*, Rawat Publishers, Jaipur, pp. 45-57.

Narayanamoorthy, A. (1995), "Status of Indian Irrigation", *Man and Development*, Vol. 17, No.4, December, pp. 49-56.

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

Narayanamoorthy, A. (1996a), "Electric Pumpset and Groundwater Management: Macro and Micro Evidence of India", *Water Resources Journal*, No. ST/ESCAP/SER.C/189, June, pp. 24-33.

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

Narayanamoorthy, A. (1997), "Drip Irrigation: A Viable Option for Future Irrigation Development", *Productivity*, Vol. 38, No.3, October-December, pp. 504-511.

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

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

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

Puranik, R.P. *et al.*, (1992), "Constraints and Problems as Perceived by Non-adopters and Adopters of Drip Irrigation Systems", *Agricultural Situation in India*, Vol.XLVII, No.1, April, pp. 33-34.

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

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

Shah, Tushaar (1993), *Groundwater Markets and Irrigation Development: Political Economy and Practical Policy*, Oxford University Press, Delhi, pp. 92-112.

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

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

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

Table 1: Distribution of Estimated Areas under Different Soil Erosion, Land Degradation and Land Utilisation Problems

(million ha)

Affected Area/Problems Area	With 1976-77 LUS and Reports till 1980-81		With 1981-82 LUS and Reports till 1984-85	
	Area	Per cent	Area	Per cent
1. Area subject to water and wind erosion	150.00	85.68	141.25	80.69
2. Area degraded through special problems:				
i. Water logged area	6.00	3.43	8.50	4.86
ii. Alkaline soils	2.50	1.43	3.58	2.05

iii. Acidic soils	--	--	4.50	2.57
iv. Saline soils including coastal sandy areas	5.50	3.14	5.50	3.14
v. Ravines and Gullies	3.97	2.26	3.97	2.27
vi. Area subject to shifting cultivation	4.36	2.49	4.91	2.80
vii. Riverine and torrents	2.73	1.56	2.73	1.56
Total problem area	175.06	100.00	174.95	100.00

Source: CWC. (1996), *Water Related Statistics*, Central Water Commission, New Delhi.

Table 2, Results of Different Research Station: Comparative Advantage of DMI Over FMI

Research Institute	Crop	Water Saving (percent)	Yield Increase (percent)	Water Requirement (mm/ha)		Crop yield (Mt/ha)	
				FMI	DMI	FMI	DMI
MPAU, Rahuri	Sugarcane	30	20	2310	1620	122.00	146.00
TNAU, Cimbatore	Sugarcane	47	29	1360	921	92.00	119.00
MPAU, Rahuri	Cotton	43	40	895	511	2.25	3.14
TNAU, Coimbatore	Cotton	79	25	700	150	2.60	3.25
TNAU, Coimbatore	Tomato	79	43	498	107	6.18	8.87
MPAU, Rahuri	Tomato	30	05	297	208	1.64	1.72
TNAU, Coimbatore	Lady's finger	84	13	535	86	10.00	11.31

MPAU, Rahuri	Brinjal	47	--	900	420	28.00	28.00
MPAU, Rahuri	Chilli	62	44	1097	417	4.23	6.09
TNAU, Cimbatore	Radish	77	13	464	108	1.05	1.19
TNAU, Coimbatore	Beet	80	56	857	177	0.57	0.89
TNAU, Coimbatore	Sweet Potato	61	40	631	252	4.24	5.89
HAU, Hissar	Potato	--	46	200	200	23.57	34.42
HAU, Hissar	Onion	--	31	602	602	9.30	12.20
TNAU, Coimbatore	Banana	77	--	2430	580	--	--
TNAU, Coimbatore	Papaya	68	77	2285	734	13.00	23.00
Jyoti Ltd, Vadodara	Lemon	81	35	42	8	1.88	2.52
Jyoti Ltd, Vadodara	Groundnut	40	66	500	300	1713.00	2841.00
Jyoti Ltd, Vadodara	Coconut	65	12	--	--		

Notes: MPAU – Mahatma Pule Agricultural University, TNAU – Tamil Nadu Agricultural University, HAU – Haryana Agricultural University.
Source: Compiled from INCID (1994).

Table 3: 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	2.60	11.05
Acid Lime	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).

Table 4: Pattern of Water Use under Drip Method and Flood Method of Irrigation

Details	GRAPES		BANANA	
	Drip Method	Flood Method	Drip Method	Flood Method
Number of Irrigation/ha	187.03	104.37	139.14	66.19
Hours Used per irrigation /ha	6.95	18.89	5.33	16.44
Horse power of the Pump-set Used	4.98	8.94	9.82	10.82

Note: All the sample farmers are using electric pump-set for irrigation.
Source: Field level data.

Table 5: Productivity, Water Consumption and Water Use Efficiency Under Drip and Flood methods of Irrigation

Method of Irrigation	Water in HP hours/ha		Yield in quintal/ha		Water Used/quintalYield	
	Banana	Grapes	Banana	Grapes	Banana	Grapes
Drip Method	7884.70	3319.36	679.54	243.25	11.60	13.61
Flood Method	11130.34	5278.38	526.35	204.29	21.14	25.84
Saving Over Flood Method						
In percentage	29.16	37.28	29.10	19.07	45.13	47.33
In absolute value	3245.64	1968.02	153.19	38.96	9.54	12.23

Source: Computed from field level data.

Table 6: Consumption of Electricity in Kwh by Drip and Non-Drip Irrigated Crops

Method of Irrigation	Banana	Grapes
Drip Method of Irrigation	5913.53	2482.77
Flood Method of Irrigation	8347.75	3958.78
Electricity Saving by Drip Irrigation		
In Percentage	29.16	37.28
In Kwh	2434.00	1476.01
In terms of Rs.	1217.00	738.00

Note: It is assumed 0.50 paise/kwh to estimate electricity cost in terms of rupees.
Source: Computed from field level data.

Table 7: Cost of Cultivation, Capital Cost, Gross Income and Subsidy Details of the Crops Cultivated under Drip and Flood Method of Irrigation.

(value in Rs)

Particulars	BANANA		GRAPES	
	Drip Method	Flood Method	Drip Method	Flood Method
1.Cost of Cultivation*	51436.66	52738.56	134506.19	147914.96
2. Gross Income	134043.75	102934.73	247817.02	211037.93
3. Profit (2 – 1)$	82607.09	50196.17	113310.83	63122.97
4. Capital Cost@				
i. Total Cost	33595.00	---	32721.00	---
ii. Cost after deducting subsidy	22236.00	---	20101.00	---
5. Subsidy	11359.00	---	12620.00	---

Note: * - including operation and maintenance cost of drip set and pump-set.

$ - farm business income (return over out-of-pocket expenses), @ - excluding cost of pump-set.
Source: Field level data.

Table 8: Senstivity Analysis of NPW and B-C Ratio Computed for Drip Irrigated Crops

Details	Without Subsidy Condition		With Subsidy Condition	
	Banana	Grapes	Banana	Grapes
Present Worth of Gross Income (Rs/ha)				
At 15 per cent discount rate	449449	1243794	449449	1243794
At 12 per cent discount rate	483228	1400166	483228	1400166
At 10 per cent discount rate	508026	1522588	508026	1522588
Present Worth of Gross Cost (Rs/ha)				
At 15 per cent discount rate	201696	703553	191814	692574
At 12 per cent discount rate	215431	789179	205287	777909
At 10 per cent discount rate	225484	856148	215159	844677
Net Present Worth (Rs/ha)				
At 15 per cent discount rate	247753	540241	257635	551220
At 12 per cent discount rate	267797	610987	277941	622257
At 10 per cent discount rate	282542	666440	292867	677911
Benefit-Cost Ratio				
At 15 per cent discount rate	2.288	1.767	2.343	1.795
At 12 per cent discount rate	2.243	1.774	2.353	1.799
At 10 per cent discount rate	2.253	1.778	2.361	1.802

Note: Computed by using discounted cash flow technique.