Article

More Crop and Profit per Drop of Water: Drip Irrigation for Empowering Distressed Small Farmers

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Abstract

In the light of the rapid decline in the irrigation water potential and increasing demand for water from different sectors in India, there is a need of the emergence of small-scale irrigation technology to conserve scarce water resources. Drip irrigation is one such technology that has been introduced to reduce water consumption in the agriculture sector, leading to sustainability of this sector. It allows farmers to cultivate crops without moisture stress even under water-scarce conditions, thereby increasing farm productivity. Earlier studies have analyzed the economics of drip irrigation in the case of high-value crops, which are mostly cultivated by rich farmers. Drip irrigation is also suitable for cultivating vegetable crops that are mostly cultivated by small farmers. However, in the Indian context, research on the effectiveness of drip irrigation is rare for these crops. We show that farmers cultivating green chilli could reduce the use of water by about two-thirds and increase productivity by more than half by adopting the drip irrigation method, compared to the same crop cultivated under conventional flood irrigation. The farm profitability too is impressive. The discounted cash flow analysis shows that the investment in drip irrigation for green chilli cultivation is economically viable even without the state subsidy. Despite such favourable outcomes, poor awareness prevailing among small farmers prevents adoption of drip irrigation. We suggest that there is a need to spread the benefits of cultivating vegetable crops under drip irrigation through a quality extension network on a continuous basis through various means. It would curtail the distress of the small farmers as well.

Keywords

Energy conservation, farm profitability, irrigation management, water productivity, water conservation.

Introduction

Water is not only critical for the sustenance of life, but also for the well-being of humans, plants and animals. Irrigation water is often considered as a means of agricultural growth, which augments the cropping intensity of high-value crops before increasing the productivity of crops significantly. Well-grounded research studies have underlined that irrigation water plays a critical role for the sustained reduction of rural poverty too. However, the water scenario today is very precarious in India.[1] On the one hand, the available potential of water for the future use has been declining at a faster rate. On the other hand, the demand for water has been increasing at an alarming rate due to its ever increasing demand for the energy, industry and domestic purposes in India (CWC, 2010; FICCI, 2013; MOWR, 1999). Despite this, much of the available irrigation water in India is applied through the conventional surface irrigation method, where the efficiency of water is very low, ranging from 35 to 40 per cent because

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of huge conveyance and distribution losses (GoI, 2004; INCID, 1994; Narayanamoorthy, 2005a; Postal, Polak, Gonzales, & Keller, 2001). The low irrigation water-use efficiency not only reduces the anticipated outcomes from investments in the water resources sector of the country, but also creates environmental problems, such as lowering of the water table due to over-exploitation of sub-surface water resources, water logging and soil salinity, thereby affecting the yields adversely.

In order to reduce the water stress in agricultural sector and to improve the efficiency of existing irrigation systems, various initiatives have been taken in India in recent years. Of these, drip irrigation has received substantial attention through central and state governments. In drip irrigation, water is supplied straight to the crop root zone through a well-structured pipe network, where the efficiency of water use is extremely high as it substantially reduces the evaporation, conveyance and distribution losses of water (Dhawan, 2002; INCID, 1994; NCPA, 1990). In addition to the reduced water consumption, drip irrigation also helps reduce the cost of cultivation in operations, such as fertilizers, labour, tilling and weeding, when compared with the conventional irrigation (Narayanamoorthy, 1997, 2003, 2005a, 2009).

Indian farmers, especially the smallholders, have been in distress for more than a decade now because of severe water scarcity, increased cost of cultivation and low productivity and profitability from crop cultivation (Deshpande & Arora, 2010; Narayanamoorthy, 2006a, 2006b, 2007). Drip irrigation seems to have solved all these problems and help reduce the distress of the farmers. Studies carried out using both experimental and field survey data at different regions of India have shown that the water saving and water-use efficiency of different crops cultivated under drip irrigation are significantly higher when compared with those under flood irrigation (Dhawan, 2002; MOWR, 2006; Narayanamoorthy, 2004a, 2005a, 2009; Shreshta & Gopalakrishnan, 1993). Since moisture stress is completely absent in drip irrigation, the productivity of crops is found to be significantly higher than those cultivated under flood irrigation (Namara, Upadhyay, & Nagar, 2005; Narayanamoorthy, 2004b; Shah & Keller, 2014). The profitability of crops is also found to be substantially higher under drip irrigation mainly because of the increased productivity and reduced cost of cultivation. While conducting research on various economic benefits of drip irrigation, including profitability, most of the studies have focused only on the widely spaced fruit and vegetable crops. Nonetheless, drip irrigation is not only suitable for widely spaced crops, but it is also highly suitable for many narrowly spaced crops including chilli, which is mainly cultivated by small farmers. Importantly, in recent times, a large number of farmers have started cultivating chilli by adopting drip irrigation. What could be the main reasons for it? Could this be due to increased water scarcity? Or is it adopted to increase the productivity and profitability of the crop? Since chilli is a short-duration seasonal crop, could the investment made in the drip irrigation system be economically viable? Although studies on the economic implications of drip irrigation on different crops in India are available, they are seldom available on the economic implications of drip irrigation on short-duration crops like chilli, specifically focusing on Tamil Nadu, an extremely water-stressed state in India.[2] In view of this, this study made an attempt to fill this gap with the following objectives: (a) to analyze the operation-wise cost of cultivation of drip- and non-drip-irrigated green chilli crop; (b) to estimate the water and electricity saving due to drip irrigation employed for the cultivation of the green chilli crop; (c) to analyze the impact of drip irrigation on the productivity and profitability of the green chilli crop and (d) to find out the economic viability of drip irrigation used for green chilli crop cultivation, using the discounted cash flow technique.

Study Area and Method

This study was carried out mainly by using farm-level survey data collected from Tamil Nadu. From the beginning of the planning period, among various states in India, Tamil Nadu has been occupying a key position with regard to agricultural production. Despite fast urban agglomeration in the state, about 44 per cent of the population is still engaged in agriculture and allied activities for their livelihood. With about 5.14 million hectares (mha) of the gross cropped area, Tamil Nadu accounted for about 2.65 per cent of India's total cropped area in 2012–13 (GoI, 2014). The production and productivity of food grain and other crops have been very impressive in Tamil Nadu when compared to other states in India. However, there has been a deceleration in agricultural growth, especially in the recent years, mainly because of water scarcity (GOTN, 2012). To attain the water-balance situation in the state, an efficient use of water is required. This can be achieved by optimizing the returns per unit of water.

Given the limited availability of irrigation water, over-exploitation phenomenon and stagnant growth in the irrigated area, there is an urgent need to increase the efficiency of the existing irrigation system in the state. In order to avoid water scarcity and to accelerate agricultural growth, the Tamil Nadu Government has been making several efforts to popularize water-conservation methods, such as drip and sprinkler irrigation by providing handsome

subsidy to farmers (GOTN, 2014).[3] As a result of such initiatives, not only the adoption of drip irrigation technology by farmers for cultivating different crops has expanded, but it has also made significant advantages already, especially in terms of water-use efficiency and productivity of certain crops (Narayanamoorthy, 2005b). Therefore, in terms of water scarcity and efficient use of existing water resources, Tamil Nadu appears to be a suitable choice to empirically evaluate the impact of drip irrigation on green chilli cultivation.

The field survey data for this study was collected from Sivaganga District, where drip irrigation is being extensively used for cultivating green chilli crop, which is fairly evident from the secondary data published by the Government of Tamil Nadu. Among the various blocks in the district, S. Pudur block was selected for a detailed study because green chilli is cultivated here on a large scale using both drip irrigation and conventional flood irrigation techniques. A total of 60 farmers comprising 30 drip and non-drip adopters each were selected for a detailed field survey. As the adoption of drip is found only among the farmers who own irrigation wells (groundwater), only farmers who cultivate green chilli using groundwater for irrigation under both drip- and flood-irrigated conditions were selected for this study. The adopters were selected using the random sampling procedure with the help of adopters' list provided by the agricultural officer of the block. On the other hand, purposive sampling method was followed to select the non-drip-irrigated farmers, who cultivate the same crop nearest to the field of drip adopters. Relevant data on the economics of drip irrigation were collected during the year 2012–13. These data form the basis for the field-level evaluation of drip irrigation. One of the main objectives of this study is to find out the economic viability of investment in drip irrigation technology for green chilli cultivation. To accomplish this, net present worth (NPW) and the benefit–cost ratio (BCR) were estimated using the discounted cash flow technique (Gittinger, 1984).[4]

Analysis and Discussion

Drip irrigation is primarily introduced to reduce water consumption in cultivation. However, studies have shown that its impact is also very significant in increasing the productivity and profitability of crops, by reducing electricity consumption and cost of cultivation of different crops. Economic viability of drip irrigation is also found to be high for different crops even without subsidies provided by the central and state governments. Let us now find out how far this is true in the case of green chilli crop cultivation, using the data collected from the sample farmers.

Managing Cost of Cultivation by Drip Irrigation

Studies carried out by using field-level data in crops like banana and grapes have already confirmed that drip irrigation reduces the cost of cultivation, especially in labour-intensive operations, such as weeding, irrigation and ploughing (Narayanamoorthy, 1996, 1997). When labour cost declines, the total cost of cultivation also plummets because labour cost constitutes a considerable portion in the total cost of cultivation. In order to understand the impact of drip irrigation on cost of cultivation of different operations, we have compared the operation-wise cost of drip- and non-drip-irrigated chilli crop.[5] According to this study, the cost of cultivation per acre is about Indian Rupees (INR) 78,500 for drip-irrigated chilli, whereas it is INR 111,200 for non-drip-irrigated chilli, that is, the farmers cultivating chilli with drip irrigation are able to save about 29 per cent of cultivation cost per acre when compared to their counterparts (non-drip adopters). A substantial amount of cost saving have been noticed in operations, such as irrigation[6] (about 93%), weeding and interculture (about 46%) and fertilizers (about 17%). These results are not surprising.

In the drip irrigation system, water is supplied directly to the crop root zone instead of the entire land. Hence, the total consumption of water is substantially reduced, leading to the reduction in the cost of irrigation. Weed growth is also reduced substantially, resulting in less amount of labour for weeding and intercultural operation for cultivating green chilli crop.[7] A considerable reduction in fertilizer consumption has also been noticed in this system of irrigation because of the use of liquid fertilizers, minimizing wastages significantly. This shows that, in comparison to the flood irrigation method, drip irrigation has the capability of reducing the cost of chilli crop cultivation considerably, thereby reducing the distress of the farmers.

Managing Water and Electricity Consumption

In recent years, farmers have been distressed because of increased water scarcity. Drip irrigation technology has put farmers' distress on rest owing to its water-conservation capability. In this system of irrigation, water is supplied directly to the root zone of the crop. Consequently, a considerable amount of water losses that occur due to conveyance, distribution and application are reduced at the field level. In experiment-based studies, water consumption is generally estimated as the depth of water applied in terms of centimetre or millimetre. It is, however, difficult to

follow the same method at the farmers' field due to changes in the horse power (HP) of the pumpset, water level in the well, varying level of delivery pipes, different sizes of water-extraction machineries, distance between place of water source and field to be irrigated, soil quality and terrain condition, among others. In view of this, water consumption is computed in terms of horse power hours of irrigation by multiplying pumpset horse power with hours of water used by farmers with drip and without drip.

The analysis of survey data shows that water conservation is substantial due to the use of drip irrigation in green chilli cultivation. The number of irrigation used for drip-irrigated crop (about 110 times) is substantially higher than that of flood-irrigated crop (90 times). However, the duration of each turn of irrigation is only about 1.95 hours per acre under drip irrigation against the 6.20 hours per acre under flood irrigation. The total water used for drip-irrigated green chilli crop is about 617 HP hours per acre, whereas the same for non-drip-irrigated green chilli crop is about 1,674 HP hours per acre. This means that farmers employing drip irrigation are able to save about 1,058 HP hours of water per acre, a saving of about 63 per cent more than flood irrigation. Since farmers are able to supply the required quantity of water at the required time exclusively at the root zone of the crop under drip irrigation, substantial water conservation is achieved. On the other hand, their counterparts using flood irrigation are unable to achieve this. The water quality used under flood irrigation is much better than that under drip irrigation. However, farmers practising flood irrigation reported that they were not able to provide adequate quantity of water during the time of crop growth mainly due to water scarcity and frequent interruptions in electricity supply. Therefore, their green chilli crop had faced either moisture stress or excess wetting during the crop season, significantly impacting the crop growth. Quite a few sample farmers have reported that frequent interruptions in electricity supply and water scarcity are the important factors for adopting the drip irrigation method for green chilli cultivation.

One of the important advantages of drip irrigation is the saving of electrical energy used for operating irrigation pumpsets, which is not adequately highlighted by the existing studies while analyzing the economics of drip irrigation. By reducing the consumption of water, drip-irrigated crop perceptibly curtails the working hours of pumpset leading to the reduction in the required quantum of electricity. In this study, we have estimated electricity saving in green chilli cultivation by assuming that 0.750 kilowatt-hour (kWh) of power is used per HP for every hour of pumpset operation, which is also supported by some earlier studies (Shah, 1993). According to this estimate, the consumption of electricity under drip irrigation is only about 462 kWh per acre against 1,256 kWh per acre under flood irrigation. That is, the adopters of drip irrigation technology are able to save an amount of 793 kWh of electricity from every acre of green chilli cultivation in the method of flood irrigation. Electricity saving generates a significant social benefit or reduces significant social costs. There is every possibility that the same amount of electricity can be saved by adopting drip irrigation, which will increase significantly when farmers adopt this technology in water-intensive annual crops, such as sugarcane and banana, where this technology is increasingly being adopted in India (Narayanamoorthy, 2009).

Productivity Advantages from Drip Irrigation

Two main reasons identified for increased distress among the farmers are: low productivity and increased cost of cultivation. In addition to water consumption, drip irrigation helps increasing the productivity of crops to a considerable extent by completely reducing the moisture stress. This is clearly evident from this study. The productivity of green chilli cultivated under drip irrigation (118 quintal per acre) is about 53 per cent higher than that under flood irrigation, which is only 77.40 quintal per acre. How does the productivity of green chilli crop increase substantially under drip irrigation? Five important reasons have been observed in this regard. First, the moisture stress for crop under drip irrigation is avoided because of its ability to supply the required quantity of water at the required time. This results in an increase in the plant growth, leading to more canopies from which more flowers and green chilli are produced. Second, the supply of water only at the root zone of the crop prevents water flow to other parts of the land, leading to a considerable reduction in weed growth. Third, the supply of water at regular intervals also allows the crop to absorb the fertilizers without any big losses through leaching and evaporation. Fourth, premature dropping of green chilli is reported to be less under the drip irrigation method because of the absence of moisture stress as compared to flood irrigation. Fifth, the better growth of plant under drip irrigation allows for the extendable harvest of green chilli which is not possible under flood irrigation. In view of relatively less use of yield-increasing inputs (cost of cultivation) under drip-irrigated green chilli as compared to the same with non-drip-irrigated condition, the productivity increase could be because of the adoption of drip irrigation. Apart from increasing the productivity of crops in an absolute term, drip irrigation also helps enhancing the water and electricity productivity of chilli crop. These are considered to be the important

advantages of drip irrigation in view of the increased scarcity of water and electricity experienced in the recent years in India.

Profitability from Crops with Drip Irrigation

Although water saving and productivity gains are substantial for green chilli cultivated under drip irrigation, farmers may hesitate to adopt this newly introduced irrigation method unless it is shown to be profitable to them. Therefore, it is important to understand the relative profitability of green chilli cultivated under the drip- and flood-irrigated methods. The total cost of cultivation that is considered for calculating the profitability of green chilli crop is calculated taking into consideration only the variable cost, but not fixed cost components, such as interest rate and depreciation. The gross income from green chilli is calculated by multiplying total yield with the price received (varied from INR 15 to 25 per kg) from the market by the farmers. To calculate the profitability in chilli cultivation, the total cost of cultivation is subtracted from the gross value of chilli produced under both the drip- and flood-irrigated methods. According to this method, the estimated profit per acre comes to INR 221,026 for drip irrigation, whereas it is only INR 91,276 for flood irrigation.[8] This means that farmers cultivating green chilli under drip irrigation are able to generate an additional profit of INR 129,750 per acre over the conventional flood irrigation. The important questions that arise here are: How do the farmers cultivating chilli under drip irrigation make substantial profit? Whether this is due to the effect of productivity or the effect of price? As reported earlier, farmers selected for this study have cultivated more or less uniform variety of green chillies. Therefore, they received almost the same price for their crop harvested from drip- and flood-irrigated fields. This means that this higher profit is purely because of the yield effect under drip irrigation and not due to any price effect. An interesting point that surfaces from this analysis of un-discounted profit is that the farmers will also be able to repay the whole capital cost of the drip system (details of capital cost required for drip irrigation is provided in the following section) from the profit of the very first year itself.

Economic Viability of Investment in Drip Irrigation

Installation of drip irrigation technology in the field involves a certain amount of fixed investment, which varies from crop to crop. Therefore, one must study whether the investment is economically viable to the farmers cultivating chillies who are mostly marginal and small farmers having a land size of less than 2 ha. We have noted in the previous section that the profit (farm business income) from green chilli cultivation under drip irrigation is significantly higher than that under the conventional irrigation method. However, this profit cannot be treated as the effective (real) profit of green chilli cultivated under drip irrigation. This is because it does not take into account the capital cost of the drip-set installed for drip irrigation, its depreciation and the interest accrued on using the fixed capital for installing the drip-set in the field. More importantly, the longevity (life period of the system) of the drip-set is an important factor that determines the NPW, which in turn is a determinant of per hectare profit. For calculating the net profit in a prudent manner, all these parameters should be taken into account.

Drip irrigation is also a capital-intensive technique. Therefore, the high initial investment needed for installing the drip system remains the main hindrance for the widespread adoption of it, especially in crops like green chilli that is not water-intensive. Some of the central policy issues in this context are: How does the requirement of fixed investment affect the economic viability of green chilli cultivation under drip irrigation? To what extent the lumpiness of investment can be counter-balanced by government subsidy? In view of these reasons, there is a need to find out the economic viability of drip irrigation in green chilli cultivation under different scenarios. Generally, to answer these issues, NPW and BCR are estimated by utilizing the discounted cash flow technique, which is carried out in this study as well.

The required fixed investment is one critical factor that determines the economic viability of the drip irrigation in any crop. Therefore, let us briefly understand about the requirement of investment for drip irrigation before getting into the economic viability of the system. The capital investment required for drip irrigation varies, depending upon the crop. Narrowly spaced crops need higher fixed investment, whereas widely spaced crops require relatively low fixed investment. The lesser the requirements of tube length, emitters and drippers for widely spaced crops, the lesser is the investment. Most of the Indian states including Tamil Nadu provide almost 50 per cent of the capital cost as subsidy either through a state-sponsored scheme or through schemes sponsored by the central government to encourage the adoption of drip irrigation for different crops, considering its capital-intensive nature. In this study, the average capital cost required for installing the drip irrigation system for green chilli crop is INR 36,642 per acre without subsidy, whereas it is only INR 22,810 per acre

after deducting the state subsidy. That is, on average, farmers installing the drip irrigation system for chilli cultivation were able to realize the capital subsidy close to the tune of INR 14,000 per acre.

Having understood the capital requirements of the drip irrigation system, let us now analyze the benefit–cost pattern of investment in drip irrigation, estimated by using the discounted cash flow technique. The NPW and BCR have been computed separately by including and excluding subsidies in the total fixed capital cost of the drip-set. Economic viability analysis under different rates of discount would indicate the efficacy of investment at various levels of the opportunity cost of investment. BCR is sensitive to the discounted rate, but the degree of such sensitivity depends on the pattern of cash flows generated during the entire life period of the drip system. Therefore, it is interesting to observe the sensitivity of BCR when there is a simultaneous change in both subsidy and discount factor. Considering all these issues, we have attempted to find out answers specific to the following four important questions:

1. Is the investment in the drip irrigation system for green chilli cultivation economically viable for farmers?
2. Will the farmers be able to meet the investment made in drip irrigation technology to cultivate green chilli without subsidy on capital cost?
3. What is the payback period of drip investment?
4. What will be the trend in the NPW and BCR when the assumed life period of the drip system is 5 years?

The results of the NPW and BCR, estimated by using the actual price of green chilli received by the farmers, show that the investment in drip irrigation for cultivating green chillies is economically viable for farmers. NPW of the investment with subsidy is marginally higher than that under 'no subsidy' option in all scenarios used for analysis, which is expected. For instance, NPW at the 10 per cent discount rate, computed by assuming 5 years as the life period of the system, is INR 804,553 per acre without subsidy and INR 825,289 per acre with subsidy. This means that the capital subsidy provided by the state government enables the farmers to get an additional benefit of about INR 20,736 per acre.

BCR computed with different discount rates clearly suggests that investment in drip irrigation is economically viable for farmers cultivating green chilli crop in all scenarios, both with and without subsidies. The minimum BCR comes to 3.40 and maximum goes up to 3.43 when one estimates the same without considering subsidy. When the BCR is calculated after deducting the subsidy from the capital cost, this increases further from 3.64 to 3.66. The relatively higher BCR realized with subsidy indicates the important role played by the subsidy in augmenting the economic viability of drip irrigation in green chilli cultivation. The minimum estimated BCR of 3.40 without subsidy underlines the fact that the investment in drip irrigation for green chilli cultivation is economically viable for farmers even without availing state subsidy. This also means that farmers can realize at least INR 3.40 from every rupee of investment made in cultivating green chilli under drip irrigation.

Concluding Remarks

The study shows that cultivating green chilli under drip irrigation provides a number of benefits to farmers over flood irrigation, thereby reducing their distress, specifically that of the small farmers who have been encountering problems in reaping better profitability in crop cultivation in the recent years. Water conservation due to the adoption of drip irrigation in green chilli cultivation is estimated to be about 63 per cent over flood irrigation. Through the reduction of working hours of pumpset that occurred due to water saving, drip irrigation also helps reducing the electricity consumption over the conventional irrigation method. The productivity of drip-irrigated green chilli is more than 50 per cent higher than the same harvested using flood irrigation.

Besides water conservation and increasing productivity in absolute terms, drip irrigation has also substantially increased the water productivity and the electricity productivity, which are essential given the increased scarcity of water resources and electricity encountered by the farmers. The farm business income (undiscounted profit) of the green chilli crop, cultivated by using drip irrigation, is also substantially higher by about 142 per cent, much more than that of the profit realized from the same crop cultivated with conventional flood irrigation. We find that investment in drip irrigation for cultivating green chillies is economically viable under all conditions, with and without subsidies as well as under different discount rates. Besides, the farmers would be able to repay the entire capital cost incurred in installing the drip-set for cultivating green chillies from the profit of the very first year itself.

The study suggests that the cultivation of green chilli crop and similar vegetable crops under drip irrigation would greatly benefit, especially the small farmers.[9] Not only in Tamil Nadu but also elsewhere in the country, farmers are unable to increase the productivity of vegetable crops due to inadequate water supply through conventional flood irrigation. Hence, small farmers get low

profits. Water availability for the irrigation purpose is going to be reduced in the future owing to multiple reasons (e.g., Amarasinghe & Smakhtin, 2014). This is expected to create serious problems for farmers in cultivating crops under conventional flood irrigation. The increased scarcity of water would create serious problems for small farmers who mostly rely on vegetable cultivation for their livelihood. Therefore, promoting drip irrigation would curtail the distress of small farmers.

Green chilli is cultivated predominantly in many states, but most of the farmers are unaware that drip irrigation is economically viable even without availing state subsidy. Therefore, there is a need to spread the benefits of cultivating vegetables under drip irrigation through a quality extension network on a continuous basis through various means. Our study explicitly shows that investment in drip irrigation technology is economically viable for small farmers who cultivate green chillies. However, it has also been observed that the initial investment required for installing the drip irrigation system for vegetables like green chilli is beyond their reach due to the lack of financial resources. Efforts should be made to provide the drip irrigation system at low cost, especially to small farmers who cultivate vegetable crops. This can be achieved with the help of better R&D activities.

This study reveals how the farmers cultivating green chilli can reap more profit from every drop of water. The results of the study can be applied to most vegetable crops that are cultivated by smallholders. The INCID (1994) study shows that more than 80 crops can be cultivated profitably even under the water-scarce condition in India. Therefore, concerted efforts should be made to increase the adoption of drip irrigation as much as possible to conserve water and to reduce the distress of the smallholders. The problem of water scarcity is rapidly increasing because of increased demand not only from the agricultural sector, but also from other sectors in India. Since drip irrigation is proved to be an efficient water-conservation method, all possible efforts should be made to avert the water scarcity issue in the future.

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Notes

1. Further details on the current and future supply of and demand for water for the whole of India are provided in MOWR (1999) and CWC (2010).
2. Green chilli is a commonly cultivated vegetable crop in India which can also be cultivated under drip irrigation. However, detailed studies focusing on the economics of green chilli crop under drip irrigation are not available. In fact, to our knowledge, not even a single study has been published on the economics of green chilli cultivation under drip irrigation in any of the leading journals in India.
3. Though initiatives to popularize the micro-irrigation started as early as 1991 in the State, the progress has not been very appreciable mainly because of poor awareness about the usefulness of micro-irrigation among the farmers. The Government of Tamil Nadu aimed to improve the income of the farmers by two to three times within next 5 years. In this regard, it had announced, in its budget of 2011–12, an ambitious programme for increasing the adoption of micro-irrigation system, wherein the small and marginal farmers will get 100 per cent subsidy for putting up micro-irrigation systems, while all other farmers will get 75 per cent subsidy (GOTN, 2012, 2014).
4. We have followed the methodology of Gittinger (1984) for estimating NPW and BCR. Since fixed capital is required for adopting drip irrigation in any crop, it is necessary to take into account the income and cost stream for the whole lifespan of drip investment. But, it is difficult to unearth the actual cash flows for the entire lifespan of drip investment because of the absence of observed temporal information on benefits and costs. Therefore, a total of four realistic assumptions are used to estimate the cash inflows and outflows for drip investment: (i) the life period of the drip-set is assumed to be 5 years for green chilli as followed by the INCID (1994) study; (ii) the cost of cultivation incurred and income generated through green chilli cultivation using drip irrigation is assumed constant during the entire life period of the drip-set; (iii) different rates of discount (interest rates) are considered to study the sensitivity of investment to the change in capital cost. They are assumed at 10, 12 and 15 per cent as alternatives representing different opportunity costs of capital; (iv) the cultivation technology of green chilli crop is assumed to remain constant during the entire life period of the drip-set.
5. The cost used in this study is A2+FL. As per the definition of the Commission for Agricultural Costs and Prices (CACP), cost A2+FL includes all actual expenses in cash and kind incurred in production by the farmer plus rent paid for leased-in land as well as imputed value of family labour. The CACP has been using nine cost concepts for cost calculation, the definition of which can be seen from CACP (2005).
6. All the sample farmers in both drip irrigation and flood irrigation categories have used only electrically operated pumpsets for irrigating crops which require no or very less operating expenditure. Since electricity has been supplied free of cost to all farmers in Tamil Nadu over the last three decades, the cost of human labour used for managing water supply is only considered as irrigation cost in this study.
7. Reduction in labour use is one of the important advantages of drip irrigation that has not been highlighted by the existing studies. Many farmers have reported that they started adopting drip irrigation specifically to avoid labour scarcity in crop cultivation which accentuated due to the introduction of national rural employment guarantee scheme and fast growth in construction in work in both rural and urban areas. Large amount of labour saving was observed in operations such as weeding, interculture, irrigation and land preparation. Since the major

focus of the study was on economic viability of drip irrigation, the details of labour use in green chilli cultivation were not discussed in this article.

8. As this profit is calculated only by deducting cost A2+FL from the gross value of production from green chilli crop, this should be appropriately called as farm business income.
9. The export of chilli has been rising over the last few years due to increased demand and short supply from other major producing countries, such as China and Pakistan. According to the report of vegetable statistics of 2013, India's exports of green chilli have increased from 31,002 tonnes in 2008–09 to 46,909 tonnes in 2010–11 (Vanitha, Chaurasia, Singh, & Naik, 2013).

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