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Efficiency and viability of drip method of irrigation in groundnut cultivation: an empirical analysis from South India

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Abstract

Drip method of irrigation (DMI) has the potential to save substantial water and electrical energy as well as increase the productivity of crops. Studies conducted on different high value crops have confirmed the various benefits of DMI. However, not many studies have researched the income and resource impact of drip irrigation including its benefit–cost pattern using survey data in crops like groundnut, which is an important oilseed crop in India. In this paper, an attempt has been made to fill this gap by using survey data collected from a water-scarce district from Tamil Nadu State in India. The results show that DMI can save about 34% of cultivation cost, 36% of water and electrical energy and increase about 79% of productivity over the same crop cultivated under conventional flood method of irrigation. The drip adopters are also able to generate an additional farm business income of Rs 25,911/acre (1 USD = INR 74.92, 1 acre = 4,047 m^2) over the non-drip adopters. The net present worth and benefit–cost ratio estimated using discounted cash flow technique shows that investment in drip irrigation is economically highly viable for groundnut cultivating farmers.

Keywords: Benefit–cost ratio; Drip irrigation; Farm income; Indian agriculture; Water and energy saving

Highlights

- Studies are seldom available on groundnut under drip irrigation.
- Studies have not analysed the financial viability of drip investment in groundnut using discounted cash flow technique.
- The study shows that DMI can save about 34% of cultivation cost, 36% of water and increase about 79% of crop productivity.
- The estimated NPW and BCR shows that investment in drip irrigation is economically viable.

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Introduction

Groundnut is one of the major oilseed crops cultivated across India. Known popularly as edible oilseed crop, groundnut (*Arachis hypogaea*) is cultivated mainly for human consumption. It is often referred to as the 'king' of oilseeds. It is a valuable source of nutrient and every part of groundnut has commercial value. The green leaves and stems of plants are used as animal feed. The shells of the pods acquired during threshing are also used as cattle feed. Being a leguminous crop, groundnut is also grown in crop rotation as it synthesises atmospheric nitrogen. It is cultivated in 5.53 million hectares of area which is about 19% of the total area under oilseeds in 2013–14 (GoI, 2015). Gujarat, Andhra Pradesh, Tamil Nadu and Karnataka are the major producers of groundnut in the country which together account for about 75% of the area and about 65% of its production in 2013–14. India occupies the first position in terms of area under groundnut cultivation, but the productivity of groundnut in India is very low as compared to China and the world's average. For instance, during 2012–13, the productivity of groundnut in China was 3,562 kg/ha and the world's average was 1,682 kg/ha, but it was only 1,485 kg/ha in India. Although the crop can be grown in all seasons, kharif season production accounts for the majority of the total production (see GoI, 2015).

Generally, inadequate supply of water at the critical stages of plant growth is considered to be the prime reason for low productivity of groundnut in India. To be more precise, since most oilseed crops are sensitive to water stress, adequate water supply for such a crop is very essential (NCPA, 1990; INCID, 1994). Research suggests that water stress in crops will have different kinds of impact on the yield. Moisture stress will affect the germination of seed, growth of plant, peg formation and seed fillings, all of which ultimately result in poor quality yield (Sripunitha *et al*., 2011). Since most oilseed crops have shallow roots, even 2 or 3 days of water stress can affect the yield significantly (www.ncpahindia.com). Therefore, adequate irrigation is of paramount importance to increase the size and weight of individual nuts and to have increased productivity of the crop. However, owing to looming water scarcity (see MoWR, 1999; Seckler, *et al*., 1999), farmers find it extremely difficult to supply water at regular intervals and at the required quantity for crops under the conventional flood method of irrigation (FMI). This poses a serious threat to the oilseed growers, in general, and groundnut farmers, in particular, in India.

Drip method of irrigation (DMI) promises to completely eliminate the problem of water stress for crops even under severe water scarcity condition. Unlike the conventional method of irrigation, using pipe network and emitters, water is delivered directly to the root zone of crops under DMI. This method is entirely different from the conventional method, where water is supplied to the whole crop land, instead of being provided exclusively to crops at the root zone. Under the conventional system of irrigation, excess supply of water at times proves to be a deterrent to yield for crops. By supplying water at the required time and quantity using a pipe network, DMI promises to check the excess supply of irrigation water and put an end to water losses occurring through conveyance and distribution.

Although DMI was introduced into crop cultivation in India during the 1980s, the adoption of it picked up only after the late 1990s. Owing to increased benefits and well-supported state-sponsored subsidy schemes for DMI, the area under DMI has expanded considerably from a mere 70,590 hectares in 1991–92 to 0.197 million hectares in 2009–10 and further to 3.37 million hectares in 2015–16

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(FICCI, 2013, 2016)[1]. Several studies have analysed the determinants of DMI and its impact on water saving, productivity and other parameters. With the help of sample data of 448 farmers in Gujarat and Maharashtra State, Namara *et al*. (2007) studied the economics, adoption determinants and impacts of micro-irrigation technologies. This study has shown the micro-irrigation technologies result in significant productivity and economic gains in different crops. Access to groundwater, cropping pattern, cash availability, level of education of the farmer, social status and poverty level of farmers are found to be the important determinants of micro-irrigation adoption. While studying the distributional pattern of micro-irrigation development in India through regression analysis with the use of a variety of secondary sources, Suresh *et al*. (2019) have shown that the stage of groundwater development and agro-climatic differences significantly determine the spread of micro-irrigation in India.

Many studies have shown that the state-supported subsidy is the main driver of drip irrigation adoption in India (for details, see Viswanathan *et al*., 2016; Narayanamoorthy, 2018). Malik *et al*. (2018) provide a totally different narrative. They surmise that 'the subsidy system holds the technology back, because of its technical requirements, highly bureaucratic processes and pricing incentives turn many drip providers into rent-seeking agents rather than service providers to farmers' (p. 66). In an analytical study on 'drivers of change in agricultural water productivity and its improvements at basin scale in developing economies', Kumar & Dam (2013) have very correctly indentified five major factors that determine the real water saving through the use of micro-irrigation. They are (1) type of crop, particularly the spacing between plants, (2) type of MI technology, (3) soil type (light or heavy textured soils), (4) climate (arid and semi-arid or humid) and (5) geo-hydrology (particularly the depth to the groundwater table). In a field survey data-based study carried out in IGNP command area in Rajasthan with a focus on water saving and social benefits from micro-irrigation, Kumar (2016) found that expansion in area under irrigation, shifting of cropping pattern to high value crops, increase in yield of crops and also significant increase in water productivity were due to the adoption of sprinkler irrigation with *diggie* (which is a local system created to store canal water).

Several studies analysed the impacts of DMI on various parameters including water saving and productivity, which are considered to be the major benefits of this new irrigation technology. DMI is found to enhance the productivity of different crops and that too at a reduced cost of cultivation (Shreshta & Gopalakrishnan, 1993; Narayanamoorthy, 1996, 1997, 2004a, 2005; Postal *et al.*, 2001; Dhawan, 2002; Namara *et al*., 2005). Field survey data-based studies on high value crops such as banana, grapes and sugarcane have shown that it can save water by about 30–40%, increase productivity by about 30–45% and also lower the cost of cultivation considerably as compared to the same crops cultivated under FMI with similar environment.

DMI is a system that needs to be installed in the field and, therefore, it obviously requires fixed capital investment. Thus, this has formed the basis of several studies which tried to find out the impact of DMI on different parameters of crop cultivation, including its economic viability in different crops, using both experimental and field level data (see INCID, 1994; Narayanamoorthy, 1997, 2003, 2004a, 2004b; AFC, 1998; Dhawan, 2002; Namara *et al*., 2005). By employing discounted cash flow

[1] There has been significant progress in area under micro-irrigation in India. India's total area under micro-irrigation (includes drip and sprinkler irrigation) was 7.73 million hectares as of 2015–16. Of this, drip irrigated area accounted for about 44%. For more details on the development of micro-irrigation, see FICCI (2016).

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technique, a few studies have also demonstrated that the investment in drip irrigation is economically viable for farmers, even without subsidy (see Narayanamoorthy, 1997, 2004a, 2004b).

Many studies are available on the impact of DMI on various crops, but credible field data-based studies on groundnut cultivation using field level survey data are not available in India[2]. Because of inherent problems associated with the surface method of irrigation and increased water scarcity, farmers are unable to supply water at the required time and interval for groundnut crop which eventually increases moisture stress for crops. The productivity of groundnut crop has been one of the lowest in the world despite farmers using required yield-increasing inputs. All these are bound to have serious implications on groundnut cultivation. The experimental data-based studies carried out in different locations show that the groundnut cultivated under DMI increases the productivity by about 20–30% and saves water by about 40–60% over the method of FMI (see Singh & Maurya, 1992; INCID, 1994; Biswas, 2010; Chauhan *et al*., 2013). However, one cannot completely rely on the results generated from experimental data for policy decisions as they vary considerably from the field level results. Moreover, the existing studies have not attempted to study whether the investment in DMI is economically viable for seasonal oilseed crops like groundnut.

In view of this, one needs to find out answer to questions such as: What drives the farmers to cultivate groundnut crop under DMI? What is the impact of it on water saving and productivity of groundnut? How much additional income can be generated by adopting DMI in groundnut cultivation? Is the investment on drip irrigation economically viable for farmers without subsidy? Recent studies have provided very strong evidence of the benefits of using DMI in cultivation of crops, in general, and high value crops (grapes, banana, sugarcane, cotton, etc.), in particular (Viswanathan *et al*., 2016). However, studies have not intensively analysed the economic viability of DMI, especially focusing on oilseed crops. In this paper, therefore, an attempt has been made to fill this gap by using field level data collected from a relatively water-scarce district in Tamil Nadu State located in South India with the following objectives:

1. To find out the operation-wise cost saving due to DMI in groundnut cultivation.
2. To estimate the water and electricity saving due to DMI in groundnut cultivation.
3. To study the impact of DMI on the productivity of groundnut crop.
4. To study the relative income of drip and non-drip irrigated groundnut crop.
5. To estimate the economic viability of drip investment in groundnut cultivation with and without capital subsidy under different discount rates.

Empirical settings and method

The study has been carried out primarily using field survey data collected from the sample farmers in Sivagangai district of Tamil Nadu, which is a major southern state in India. Sivagangai district is located in the south-east part of Tamil Nadu State and has been selected purposively for the study because it is known for water scarcity. With very little coverage of canal irrigation, the district's agriculture has predominantly relied on two sources, namely, tank irrigation (which is not assured, relying on monsoon rainfall)

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[2] Groundnut is one of the important commonly cultivated oilseed crops of the country which can also be cultivated under drip method of irrigation. But, we seldom see any analytical study on this subject in the literature. In fact, to our knowledge, no detailed study has been published on the economics of groundnut cultivation under drip method of irrigation, especially in any of India's premier journals.

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and groundwater (see GoTN, 2014). In order to contain the water scarcity problems, farmers have resorted to using DMI in crops like sugarcane, banana, chilli, groundnut, etc., in the district, especially in recent years. Groundnut crop has been cultivated in different parts of the district, but its cultivation is relatively higher in Kalaiyarkovil block of the district because of its soil suitability. Using groundwater, farmers have traditionally cultivated groundnut crop in this block under the conventional FMI. However, in recent years, due to over-exploitation of groundwater, farmers are unable to cultivate the groundnut crop under the FMI. As DMI helps to cultivate crops even under severe water scarcity, farmers have started adopting it for cultivating groundnut in this region. Given relatively higher adoption of DMI in groundnut cultivation, Kalaiyarkovil block has been selected for conducting this detailed study.

The study primarily aims to compare the profitability, including the economic viability of groundnut crop cultivated under drip and non-drip irrigated conditions. Therefore, a total of 100 farmers, consisting of 50 adopters and 50 non-adopters of DMI, has been selected from the Kalaiyarkovil block. While the adopters have been selected using random sampling procedure with the help of an adopters' list provided by the Agricultural Officer of the block, a purposive sampling method has been 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 DMI have been collected from this sample of 100 farmers for 2013–14 using pre-tested interview schedule.

One of the major objectives of the paper is to find out the economic viability of investment in drip irrigation in groundnut cultivation. To accomplish this objective, net present worth (NPW) and benefit–cost ratio (BCR) are estimated using discounted cash flow technique (Gittinger, 1984). 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 pools together the total benefits with the total costs taking into account items such as cost of capital and depreciation costs of the drip set. As per 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 closely related to NPW as it is obtained just by dividing the present worth of the benefit stream with that of the cost stream. If the BCR is more than one, then the investment on any project can be considered as economically viable. Obviously, a BCR greater than one implies that the NPW of the benefit stream is higher than that of the cost stream, which is clearly detailed by Gittinger (1984). The NPW and BCR can be mathematically defined as follows:

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

$$\mathrm{BCR} = \frac{\sum_{t=1}^{t=n} \frac{B_t}{(1+i)^t}}{\sum_{t=1}^{t=n} \frac{C_t}{(1+i)^t}} \tag{2}$$

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.

As reported earlier, fixed capital is required for adopting drip irrigation in any crop and, thus, it is necessary to take into account the income and cost stream for the whole life span of drip investment. However, it is difficult to generate the actual cash flows for the entire life span of drip investment

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because of the absence of observed temporal information on benefits and costs. Therefore, the following realistic assumptions are employed to estimate the cash inflows and cash outflows for drip investment:

1. The life period of the drip-set is primarily assumed to be five years as followed by the INCID (1994) study and on that basis NPW and BCR are worked out. Alternatively, NPW and BCR are also worked out by assuming the life period as ten years based on the experience gathered from the adopters of drip irrigation.
2. The cost of cultivation incurred and income generated through groundnut cultivation using DMI is assumed to be constant during the entire life period of drip-set.
3. Two different rates of discount (interest rates) are considered in order to understand the sensitivity of investment to the change in capital cost. They are assumed at 10 and 15% as alternatives representing different opportunity costs of capital.
4. The technology used for cultivating groundnut crop is assumed to remain constant during the entire life period of drip-set.

Groundnut cultivation in India

This study focuses on groundnut cultivation and, therefore, it would be useful to understand the overall state of cultivation of this crop in India before getting into the analysis of survey data. Groundnut is grown widely in more than 100 countries in the world including the tropical and sub-tropical nations. As per FAO statistics, until 1991 India was the largest producer of groundnut in the world, but by 2001 China had overtaken India and now it holds the first position. Although India possesses the largest area under groundnut cultivation in the world, it continues to remain second among the top groundnut producing countries, because of poor crop yield (FAO, 2011; GoI, 2015).

In India, groundnut has traditionally been cultivated for edible purposes. It is predominantly cultivated under rainfed condition; less than one-fourth of its area was under irrigation coverage during 2013–14. Until a few years ago, groundnut used to be the largest produced oilseed in India. However, its share has been declining due to a sharp rise in other oilseeds' production such as soyabean and rapeseed and mustard. For instance, the area under groundnut increased from 4.49 mha in 1950–51 to 8.31 mha in 1990–91, but thereafter there has been a declining trend in its area. As a result of fluctuations in area, the production of groundnut has also been fluctuating over the years (see Table 1). Nevertheless, groundnut yield seems to show an upward trend, especially after 2000–01. At the state level, although groundnut has been cultivated in most states in India, it has been cultivated predominantly in states like Gujarat, Andhra Pradesh, Tamil Nadu, Rajasthan, Karnataka and Maharashtra. Gujarat and Andhra Pradesh, together, accounted for about 58% of India's total groundnut area during 2013–14. Owing to the predominant cultivation of groundnut under rainfed condition where moisture stress is common, the productivity of the crop continues to be very low in India.

Results and discussion

To understand the significance of DMI in saving water and increasing productivity of crops, a number of field data-based studies have been carried out on different crops; but, studies on groundnut cultivation

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Table 1. Trends in area, production and yield in groundnut in India, 1950–51 to 2014–15.

Year	Area (mha)	Production (mt)	Yield (kg/ha)	Irrigation coverage (%)	% of groundnut area to total oilseeds area
1950–51	4.49	3.48	775	NA	41.84
1960–61	6.46	4.81	745	3.00	46.91
1970–71	7.33	6.11	834	7.50	44.05
1980–81	6.80	5.01	736	13.30	38.64
1990–91	8.31	7.51	904	18.60	34.41
2000–01	6.56	6.41	977	17.60	28.81
2010–11	5.86	8.26	1,411	22.40	21.53
2012–13	4.72	4.70	995	26.00	17.82
2013–14	5.51	9.71	1,764	27.76	19.64
2014–15	4.76	7.40	1,552	26.66	18.60

Sources: Computed utilising data from GoI (2015) and www.dacnet.nic.in.
mha, million hectares; mt, million tonnes; NA, not available; kg/ha, kilogram per hectare.

are seldom available. Before analysing the impacts of DMI on different parameters, the basic characteristics of the sample farmers are briefly described. Data presented in Table 2 show that apart from the sample farmers' age and farming experience, the drip adopters' condition seems to be better than the non-drip adopters in all other characteristics. The differences between the two categories of farmers are perceptible, especially in land- and irrigation-related parameters. For instance, the average landholding size of the drip adopters was 7.30 acres (1 acre = 4,047 m^2), whereas it was only 4.36 acres for non-drip adopters. Drip irrigation requires fixed capital to install the system in the field and, therefore, the large farmers who are relatively better off in terms of resources have adopted this relatively new water saving technology. This is expected because most adoption-related studies have confirmed that early adopters of any new technologies are relatively educated and resourceful farmers (see Namara *et al.*, 2007).

Table 2. Socio-economic characteristics of the sample farmers.

Characteristics	Unit	Average value	
		FMI	DMI
Age of farmer (agriculture head)	Year	51.74	44.84
Education of farmer	Year	4.16	8.94
Farming experience of farmer	Year	33.58	26.18
Landholding size	Acre	4.36	7.30
Net cropped area	Acre	4.12	7.30
Gross cropped area	Acre	6.58	13.61
Net irrigated area	Acre	4.12	7.30
Gross irrigated area	Acre	6.58	13.61
Land use intensity	Per cent	94.49	100.00
Cropping intensity	Per cent	159.71	186.44

Source: Computed using field survey data.
FMI, flood method of irrigation; DMI, drip method of irrigation.
1 acre = 4,047 m^2.

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Table 3. Operation-wise cost of cultivation of drip and flood irrigated groundnut, in Rs/acre.

			Gain over FMI	
Operation	DMI	FMI	Amount	Per cent
1. Preparatory works	2,768	3,314	546	16.48
2. Seed and sowing	5,575	6,612	1,037	15.68
3. Fertilisers	2,558	4,603	2,045	44.43
4. Farm yard manures	2,768	4,395	1,628	37.03
5. Pesticides	465	536	71	13.25
6. Weeding and interculture	1,457	7,518	6,061	80.62
7. Irrigation	437	4,038	3,601	89.18
8. Harvesting	4,711	3,326	−1,385	−41.63
9. Transport and marketing	2,218	1,117	−1,101	−98.53
10. Others	766	526	−241	−45.81
Total cost (A2 + FL)	23,723	35,985	12,263	34.08

Source: Computed using field survey data.
FMI, flood method of irrigation; DMI, drip method of irrigation.
The cost of cultivation referred to in this paper is cost A2 + FL as per CACP definition.
1 USD = INR 74.92; 1 acre = 4,047 m^2.

Cost of cultivation

In recent years, for various reasons, the cost of cultivation of most crops has spiralled to an unimaginable extent (see Narayanamoorthy, 2013; Narayanamoorthy *et al*. 2015). Although the costs of most farm inputs have risen, the cost of irrigation water is arguably the significant one. DMI promises to help in reducing the cost of cultivation drastically, which is not highlighted by many earlier studies. DMI reduces the cost of cultivation, especially in operations like irrigation, weeding, ploughing and preparatory works. To study the impact of DMI on various operational costs of cultivation, we have compared each of the operations of drip irrigated groundnut with the same crop cultivated under flood irrigated condition.

The data on operation-wise cost of cultivation presented in Table 3 shows a difference of about 34% in the total cost of cultivation[3] between the two methods of irrigation. As confirmed by earlier studies on other crops, among the various operations, a substantial amount of cost saving is noticed in operations like irrigation[4] (89.18 percent), weeding and interculture (about 80.62%) and preparatory works (about 16.48%). The results are not at all surprising, rather are along the expected lines. The reduced consumption of water under DMI helps reduce the cost of irrigation over the method of flood irrigation. Relatively fewer requirements of ploughing and other preparatory works for cultivating groundnut

[3] This cost is A2 + FL. By the definition of 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 (2015).

[4] For irrigating crops, all the sample farmers in both DMI and FMI categories have used only electrically operated pumpset which requires very less operating expenditure. In this study, irrigation cost includes only the human labour costs that are used for managing water supply to crops because electricity has been supplied free of cost to all farmers in Tamil Nadu over almost the last three decades.

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under DMI help reduce the cost of preparatory works. Since water is supplied only at the root of the crops and not to the non-crop zone under DMI, weed growth is reduced substantially. As a result of reduced weed growth, the requirement of labour for weeding and interculture operation in groundnut cultivation is eventually reduced[5]. In sum, the results clearly show that DMI has the capability of reducing the cost of cultivation in groundnut crop.

Water and electricity saving

One of the major advantages of DMI is water saving. Since water is supplied directly to the root zone of the crop under DMI, water losses occurring due to conveyance, distribution and application at the field level are reduced. Under experimental-based studies, water consumption is usually estimated as depth of water applied (in terms of centimetre or millimetre). It is difficult to follow the same method at the farmers' field because of changes in the horse power (HP) of the pumpset, water level in the well, varying level of delivery pipes, condition of the water extraction machinery, distance between place of water source and field to be irrigated, quality of soil, terrain condition, etc. Given this, water consumption is measured in terms of horse power (HP) hours of irrigation. HP hours of water consumption are computed by multiplying HP of the pump-set with hours of water used.

It is evident from Table 4 that DMI in groundnut cultivation saves an enormous amount of water. Although the number of irrigations used for drip irrigated crop (25 times) are substantially higher than that of flood irrigated crop (13 times), the duration of hours used for each turn of irrigation is only about 2.04 hours under DMI as against the use of 5.96 hours per acre under FMI. As a result, the total water used for drip irrigated groundnut comes to about 284 HP hours/acre, whereas the same comes to about 445 HP hours for non-drip irrigated groundnut crop. This means that drip farmers are able to save about 161 HP hours of water per acre, which is about 36% saving over FMI. Since farmers are able to supply the required quantity of water at the required time exclusively at the root zone of the crop under DMI, a substantial water saving is achieved. The same-area farmers are unable to accomplish this when groundnut is cultivated under FMI. Although the water usage under the FMI is much higher than under the DMI, farmers following FMI reported that they were not able to supply an adequate quantity of water over the period of crop growth mainly due to water shortage in the well and also due to frequent interruptions in electricity supply. Therefore, their groundnut crop had faced either moisture stress or excess wetting during the crop season, which impacted on the crop growth. In fact, quite a few sample farmers have reported that frequent interruptions in electricity supply, water scarcity and non-availability of labour are the three important factors instrumental for adopting the DMI for groundnut cultivation.

Another advantage of DMI is that it saves an enormous amount of electrical energy while operating irrigation pumpsets. The reduced consumption of water by drip irrigated crop obviously curtails the

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[5] Reduction in labour use is perceived as one of the biggest advantages of drip method of irrigation by the farmers in today's context. Many farmers have reported that they started adopting the drip method of irrigation specifically to avoid labour scarcity in crop cultivation which was accentuated due to the introduction (in the year 2006) of national rural employment guarantee scheme and fast growth in construction work in both rural and urban areas. As per our estimate, drip farmers were able to reduce 24 days of wage labour as compared to farmers cultivating groundnut under conventional method of irrigation. A 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 the financial viability of the drip method of irrigation, the details of labour use in groundnut cultivation are not discussed in this paper.

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Table 4. Water use, electricity consumption and productivity of drip and flood method irrigated groundnut.

	Particulars	Method of irrigation	Average	Savings over FMI	
				In value	In %
1	Number of irrigations/acre	DMI	25.36	−11.94	−88.97
		FMI	13.42		
2	Hours required per irrigation/acre	DMI	2.04	3.92	65.77
		FMI	5.96		
3	HP hours of water used/acre	DMI	283.50	161.20	36.25
		FMI	444.71		
4	Electricity consumption (kwh/acre)	DMI	212.63	120.90	36.75
		FMI	333.53		
5	Productivity (quintal/acre)	DMI	23.03	10.19	79.35
		FMI	12.84		
6	Water productivity (kg/hp hours of water)	DMI	8.12	5.24	181.35
		FMI	2.89		
7	Electricity productivity (kg/kwh)	DMI	10.83	6.98	181.38
		FMI	3.85		
8	Cost of cultivation (Rs/quintal)	DMI	23,723	12,263	34.08
		FMI	35,985		
9	Value of output (Rs/acre)	DMI	59,873	13,649	29.30
		FMI	46,224		
10	Farm business income (Rs/acre)	DMI	36,150	25,912	253.07
		FMI	10,239		

Source: Computed using field survey data.
FMI, flood method of irrigation; DMI, drip method of irrigation; hp, horse power; kwh, kilo watt hour.
1 acre = 4,047 m^2; 1 quintal = 100 kg; 1 USD = INR 74.92.

working hours of the pumpset reducing the required quantum of electricity. We have estimated the electricity saving in groundnut cultivation by assuming that 0.750 kWh of power is used per HP for every hour of pumpset operation, which is also followed by some earlier studies (see Shah, 1993; Narayanamoorthy, 2004a). As per our estimate, the consumption of electricity under DMI is only about 213 kWh/acre as against 334 kWh/acre under FMI. This means that the drip adopters are able to save an amount of 121 kWh of electricity from every acre of groundnut cultivation over the FMI. In water-intensive annual crops such as sugarcane and banana such a saving in electricity due to DMI is found to be significantly very high and has proved to be a panacea for the water-stressed regions of Maharashtra (see Narayanamoorthy, 2009).

Productivity increase

Drip method of irrigation also helps to increase the productivity of crops to a considerable extent by reducing their moisture stress, which is also observed in this study. Table 4 clearly depicts that the productivity of groundnut cultivated under DMI (23 quintal/acre) is about 79% higher than that under FMI, which is only 13 quintal/acre. There arises the question as to what catapulted the productivity of groundnut under DMI? Could it be due to higher application of yield-increasing inputs under DMI? The farmers have outlined the following five main reasons for increased yield. First, the moisture stress for crops under DMI is reduced because of its ability to supply the required quantity of water at the

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Table 5. Cost and income details of drip and flood irrigated groundnut, in Rs/acre.

Particulars	DMI	FMI	Gain over FMI	
			Amount	Per cent
1. Gross cost of cultivation	23,723	35,985	12,263	34.08
2. Gross value of production	59,873	46,224	13,649	29.53
3. Profit (farm business income)	36,150	10,239	25,912	253.07
4. Capital cost of DMI (without subsidy)	35,022	–	–	–
5. Subsidy for DMI	14,990	–	–	–
6. Capital cost of DMI (with subsidy)	20,032	–	–	–

Source: Computed using field survey data.
FMI, flood method of irrigation; DMI, drip method of irrigation.
Cost of cultivation used in this study refers to cost A2 + FL.
1 USD = INR 74.92; 1 acre = 4,047 m^2.

required time. This resulted in increase in germination of seed, peg formation, more flowers in canopies and seed filling. Second, supply of water only at the root zone of the crop prevents water flow to other zones and, therefore, weed growth is considerably reduced. Third, the supply of water at regular intervals also allowed the crop to absorb the fertilisers without any immense losses through leaching and evaporation. Fourth, seed filling of groundnut are reported to be better under drip method because of the absence of moisture stress as compared to FMI. Fifth, the better growth of plants under DMI allows for increased yield of groundnut which is not possible under FMI. Given the relatively lesser use of yield-increasing inputs (confirmed earlier by operation-wise cost of cultivation) under drip irrigated groundnut as compared to the same with non-drip irrigated condition, one can conclude that the productivity gain in groundnut could be due to the adoption of DMI. Besides increasing absolute productivity of crops, DMI also helps in enhancing the water and electricity productivity of the crop considered for the analysis (see, rows 6 and 7 in Table 4) which is essential in view of the increased scarcity of water and electricity experienced in recent years in India.

Enhanced farm business income

It is very much evident from the above analysis that DMI indeed promotes water and electricity saving and augments crop productivity too. Now we shift our attention to the relative profit levels of groundnut. It is important to highlight here that the total cost of cultivation that is considered for calculating the profitability of groundnut crop is calculated taking into consideration only the variable cost, without spreading out the fixed cost including its components like interest rates and depreciation. The gross income from groundnut is calculated by multiplying total yield with the price received from the market by farmers. The total cost of cultivation is subtracted from the gross value of production to calculate the profit. The profit per acre estimated as per this method comes to Rs 36,150 (1 USD = INR 74.92) for DMI, but it is only Rs 10,238 for FMI (see Table 5)[6]. This means that drip irrigation helps to generate an additional profit of about Rs 25,911/acre (1 acre = 4,047 m^2) over

[6] This profit is the difference between gross value of production from groundnut crop and cost A2 + FL. This should ideally be called farm business income.

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the method of flood irrigation. It may be interesting to know how drip farmers can make a substantial profit. Is it due to increased productivity or is due to the effect of price? As mentioned in the Methodology section, farmers selected for this study have cultivated a more or less uniform variety of groundnut. Therefore, farmers were able to get the same price for the groundnut harvested from drip and flood irrigated fields. This suggests that this higher profit could be due to yield effect under DMI and not due to price effect. This analysis of undiscounted profit also reveals a crucial revelation that the farmers would also be able to repay the whole capital cost of the drip system (which is about Rs 35,022/acre without subsidy) from the profit of a single crop in a year.

Economic viability of drip investment

It is clearly evident from the analysis that the profit (farm business income) from groundnut cultivation with DMI is found to be significantly higher than the profit under conventional irrigation methods. However, this profit cannot be treated as the effective (real) profit of groundnut cultivated under DMI. The main reason for this is that it does not spread out the capital cost of the drip set, its depreciation and the interest accrued for installing the drip-set in the field. In order to calculate the net profit, all these parameters should be taken into account. Importantly, the longevity of drip-set (life period) is an important variable which also reflects the density of spread out of the fixed cost incurred for the drip system. DMI is also a capital-intensive technique and, therefore, the initial high investment needed for installing drip systems remains the main hindrance for its widespread adoption, especially in crops like groundnut which is neither an annual crop nor water-intensive. How does the requirement of fixed investment affect the economic viability of groundnut cultivation under DMI? To what extent such effect can be counterbalanced by government subsidy is one of the pressing issues that requires an immediate empirical answer. There is, therefore, a need to find out the economic feasibility of drip investment on groundnut cultivation under different scenarios taking into account all these issues. To answer these issues, we have computed both the NPW and the BCR by utilising the discounted cash flow technique, which incorporates the cost of cultivation and spread out cost of drip system over its life period.

An important factor that determines the economic viability of the drip irrigation in any crop is the required capital investment. Therefore, a brief discussion about the requirement of capital for drip irrigation is useful before studying the economic viability of the system. The capital investment required for DMI varies depending upon the nature of the crop. While narrow-spaced crops need higher fixed investment, wide-spaced crops require relatively low fixed investment (GoI, 2014). This is because of relatively less requirement of tube length, emitters and drippers. Most states, including Tamil Nadu, are providing almost 50% of the capital cost as subsidy either through a state-sponsored scheme or centrally sponsored scheme to encourage the adoption of drip irrigation for different crops since it is a capital-intensive technology. As is evident from Table 5, the average capital cost of drip-set for groundnut crop comes to about Rs 35,022/acre (1 USD = INR 74.92) without subsidy, whereas it is only Rs 20,032/acre after deducting the state subsidy.

The NPW and the BCR have been computed separately by including subsidy and by excluding subsidy in the total fixed capital cost of drip-set. Financial viability analysis under different rates of discount would indicate the efficacy 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. Keeping this in view, we have attempted to find answers

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Table 6. NPW and BCR estimated using actual price received by the sample farmers for drip irrigated groundnut.

Subsidy category	Life period assumed	Discount rate	NPW (INR/acre)	BCR
With subsidy	5 years	15%	1,03,762	2.07
		10%	1,18,827	2.10
	10 years	15%	1,64,011	2.20
		10%	2,03,917	2.24
Without subsidy	5 years	15%	90,727	1.82
		10%	1,05,199	1.86
	10 years	15%	1,50,978	2.01
		10%	1,90,290	2.07

Source: Computed using field survey data.
NPW, net present worth; BCR, benefit–cost ratio.
Estimated using discounted cash flow technique for actual price.
1 USD = INR 74.92; 1 acre = 4,047 m^2.

specifically to the following four important issues, namely: (1) Is the investment in drip system for groundnut cultivation economically viable for farmers? (2) Will the farmers be able to meet the investment in drip irrigation to cultivate groundnut 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 five years and ten years?

Table 6 presents the results of net present worth and the BCR estimated using the actual price of groundnut received by the farmers. Both NPW and BCR computed under different scenarios clearly reveal that the drip investment on groundnut cultivation is economically viable for farmers. Along the expected lines, the NPW of the investment with subsidy is marginally higher than that under the 'no subsidy' option. For instance, the NPW at 10% discount rate computed assuming five years as life period of the system comes to about Rs 1,05,199/acre without subsidy and Rs 1,18,827/acre with subsidy. This implies that farmers are able to get an additional benefit of about Rs 13,627/acre due to subsidy support.

With different discount rates, the BCR has also been computed and it clearly suggests that drip investment is financially feasible for groundnut farmers under the scenario of with and without subsidy. The minimum BCR comes to 1.82 and maximum goes up to 2.07 when one estimates the same without considering subsidy. This increases further from 2.07 to 2.24 when subsidy is deducted from the capital cost. The relatively higher BCR realised with subsidy indicates the important role played by the subsidy in enhancing the economic viability of drip irrigation in groundnut cultivation. The minimum BCR estimated comes to 1.86 without subsidy. All these clearly authenticate the fact that the investment in drip irrigation in groundnut cultivation is financially viable even without availing of a state subsidy.

The NPW and BCR are also sensitive to the life period of the drip system assumed for calculation, as the spread out of fixed capital cost will change depending upon the life period. The BCR is expected to be relatively less when one estimates the same assuming relatively lower number of life period as compared to the longer period because of higher density of the capital investment. Although the ideal life period of the drip system for groundnut cultivation is five years, the experiences of the farmers suggest that the system may work up to ten years with proper maintenance. In the worst case, the system may be expected to work only up to five years. We have specifically attempted to see to what extent the NPW and BCR are sensitive to the varying life period of the drip system. The results presented in Table 6

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show that the value of BCR and NPW increases significantly when one estimates the same, assuming ten years as life period as compared to five years as life period.

A very crucial issue with regard to the DMI adoption in crops like groundnut is how many years are needed (payback period) for the farmer to fully recover the capital investment in drip adoption. The year-wise NPW estimated under various scenarios (different discount rates with varying life period of the system) suggests that the farmers would be able to recover the entire capital cost of the drip-set from the income in the very first year itself even without 50% of subsidy from capital cost. This emphatically disproves the commonly held argument that recovering capital cost for drip investment in crops like groundnut would take a longer period.

Conclusion and recommendations

The study reveals that cultivating groundnut under DMI provides a number of benefits to farmers over FMI. It not only reduces the cost of irrigation to the tune of about 34%, but also helps reduce the cost of weeding, interculture as well as preparatory works. Water saving due to DMI in groundnut cultivation is estimated to be about 36% over FMI. DMI also helps to reduce the consumption of electricity to the tune of about 121 kWh/acre over the conventional irrigation method. The productivity difference between the two methods of irrigation comes to about 10 quintal/acre (1 quintal = 100 kg), which is about 79% higher than the same cultivated under FMI.

Increased productivity with reduced consumption of water under DMI has also increased the water productivity and the electricity productivity substantially. The profit (farm business income) generated from drip irrigated groundnut crop is also substantially higher by about INR 25,911/acre (1 USD = INR 74.92; 1 acre = 4,047 m^2) than that of the profit realised from conventional FMI. The NPW and BCR estimated using discounted cash flow technique shows that the drip investment in groundnut cultivation is economically viable under both 'with' and 'without' subsidy condition. The analysis on payback period of drip investment shows that the farmers would be able to repay the entire capital cost of the drip system incurred for cultivating groundnut from the income in the very first year itself.

The study suggests that cultivation of groundnut crop under DMI would greatly benefit farmers. DMI is indeed a boon to farmers not only in Tamil Nadu, but elsewhere in the country, especially at a time when they are struggling to increase the productivity of groundnut mostly because of moisture stress that occurs due to inadequate water supply through conventional FMI. Most times farmers are able to realise only meagre profits due to the low yield of groundnut under flood irrigated condition. Macro-level research suggests that due to various reasons, water availability for irrigation purposes is expected to be reduced in the future, which is going to pose serious problems to farmers in cultivating crops under the conventional flood method of irrigation. Increased scarcity of water will create serious problems for smallholders who mostly rely on oilseed crop cultivation for their livelihood. Therefore, promoting DMI will not only curtail the distress of groundnut growing farmers but will also help improve their livelihood opportunities.

Both the central and state governments have been implementing various special programmes to improve the agricultural sector in the study area as well as in other parts of India. While planning such programmes, the governments need to allocate a certain proportion of funds specifically for promoting oilseed crops' cultivation under DMI. Although groundnut crop is cultivated predominantly in many states, most farmers are still ignorant about the fact that groundnut cultivation under DMI is

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economically viable even in the absence of a state subsidy. This happens mainly due to poor awareness among the farmers about the various advantages of DMI in crop cultivation. Therefore, the benefits of cultivating groundnut under DMI need to be propagated through a quality extension network and special broadcast programme on a continuous basis through electronic and print media. Although the study clearly shows that drip investment is economically viable for cultivating groundnut, farmers, especially small and marginal ones, generally opined that initial investment required for installing a drip system for crops like groundnut is beyond their reach. Therefore, some well thought out oriented system may be created for providing a low cost drip system for oilseed cultivating smallholders. Maharashtra, which is a pioneering state in India in introducing drip irrigation in crop cultivation, has been making rapid progress in the adoption of drip irrigation in different crops over the years. The policies and experiences of Maharashtra State may also help Tamil Nadu State, where the present study is carried out, to revamp the incentive schemes on drip irrigation in an effective manner (Narayanamoorthy & Deshpande, 1997). Given the looming water scarcity problems in most parts of India, supporting any initiative that helps to conserve water and energy as well as augmenting productivity of crops will not only benefit the farming community but will benefit the entire country and the economy.

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Data availability statement

All relevant data are included in the paper or its Supplementary Information.

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