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Can Drip Method of Irrigation Transform Yield and Income of Horticultural Crops? Evidence of Five Crops from Tamil Nadu[@]

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ABSTRACT

The study aims to evaluate the impact of drip irrigation on crop productivity and income of the farmers cultivating five horticultural crops - brinjal, tomato, banana, watermelon, and mango—across different districts in Tamil Nadu, India. It investigates water savings, yield differences, and economic viability of drip irrigation compared to conventional flood irrigation. Data were collected from 500 farmers (250 drip irrigation adopters and 250 flood irrigation users) and the study finds that drip irrigation significantly reduces water consumption, ranging from 39 per cent to 55 per cent, compared to flood irrigation. Additionally, it was found that drip irrigation improves crop productivity by 33 per cent to 41 per cent, depending on the crop, by eliminating moisture stress and ensuring consistent water supply to the root zone. The study also calculates the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) to assess the economic viability of drip irrigation investments. Drip irrigation is economically viable even without subsidies, though subsidies enhance profitability, BCR ratios improve across all crops. Farmers using drip irrigation earn significantly higher profits; profit margins range from 52.92 per cent for brinjal to 114.50 per cent for mango. The study suggests that increased adoption of drip irrigation could mitigate water scarcity issues, improve the income of smallholders, and contribute to sustainable agricultural practices in India, especially as water resources continue to decline. However, awareness and adoption of drip irrigation remain limited, underscoring the need for government intervention to promote its widespread use.

Keywords: Drip irrigation, horticulture, Indian irrigation, water scarcity, vegetable crops.

JEL codes: Q15, Q16, Q18, Q25

I

INTRODUCTION

The major objective of this study is to find out how drip irrigation helps increase the yield and income of five different horticultural crops cultivated in five different districts in Tamil Nadu State. Production of horticultural crops in India has increased from 25 million tonnes (mt) in 1950-51 to 331 mt in 2020-21, surpassing the production of foodgrain crops (PIB, 2023). With 18 per cent of the area, horticultural crops account for about 33 per cent of the gross value of the agricultural gross domestic product in India (PIB, 2023; MoAFW, 2023). Though the production of horticultural crops has increased significantly over the last two decades in India, the productivity of most of these crops is low compared to the world's average, mainly due to water stress (MoAFW, 2023).

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Water stress during critical growth stages significantly affects the yield of horticultural crops (GOI, 2004; Rekha & Mahavishnan, 2008). Vegetable crops, particularly, are highly sensitive to water stress, and timely irrigation is essential for optimal yield (NCPA, 1990; INCID, 1994; Chauhan et al., 2013). The impact of moisture stress varies, affecting seed germination, plant growth, and the formation of pegs, ultimately leading to poor-quality produce (Rekha & Mahavishnan, 2008). Since most vegetable crops have shallow root systems, minor water shortages can significantly reduce yield (Chauhan et al., 2013; www.ncpahindia.com). Therefore, providing irrigation at the right time is crucial for enhancing the overall quality of the produce. However, increasing water shortages (MoWR, 1999; Seckler et al., 1998, 1999; CWC, 2010; Amarasinghe & Smakhtin, 2014; Narayanamoorthy, 2022) present major challenges for farmers trying to ensure adequate water supply for crops grown under the flood irrigation system.

Drip irrigation effectively addresses crop water stress even amid increasing water scarcity. Utilizing a network of pipes and emitters, drip irrigation delivers water directly to the root zone of crops, unlike flood irrigation, where water is applied across the crop land, leading to inefficiencies (INCID, 1994; Chauhan et al., 2013). Flood irrigation can hinder the productivity of vegetable crops. In contrast, drip irrigation supplies water in precise quantities, preventing over-irrigation and minimizing water loss. Research data indicates that horticultural crops irrigated through drip irrigation can achieve 30-50 per cent higher yields while conserving 40-60 per cent more water compared to flood irrigation (INCID, 1994; Rekha & Mahavishnan, 2008; Biswas, 2010; Rajaraman & Pugalendhi, 2013; Sharma & Kaushal, 2015). Additionally, drip irrigation contributes to reducing cultivation costs (Shreshtha & Gopalakrishnan, 1993; Narayanamoorthy, 1996, 1997, 2004, 2005; Dhawan, 2002; Postel et al., 2001; Namara et al., 2005; Shah & Keller, 2014). Owing to its numerous benefits and government-backed subsidies, the area under drip irrigation has expanded significantly, from 70,590 hectares in 1991-92 to 5.97 million hectares in 2019-20 (FICCI, 2013, 2016; MoAFW, 2021).

Numerous studies have assessed the benefits and economic feasibility of drip irrigation in crop cultivation using experimental data and field surveys (INCID, 1994; AFC, 1998; Narayanamoorthy, 1997; 2003; 2004; 2005; Dhawan, 2002; Namara et al., 2005). Research on high-value crops reveals that drip irrigation can save 30-40 per cent of water, increase productivity by 30-45 per cent, and lower cultivation costs than flood irrigation. Additionally, studies employing the discounted cash flow technique have confirmed that investing in drip irrigation is economically viable (Narayanamoorthy, 1997, 2001, 2004, 2008). These findings highlight drip irrigation as an efficient, cost-effective solution for improving crop productivity while conserving water resources.

Many studies have explored the effects of drip irrigation on crop cultivation, but large-scale, reliable research, specifically on horticultural crops, particularly in Tamil Nadu, is limited. Farmers face substantial difficulties with conventional irrigation methods, as ensuring a regular water supply for horticultural crops often leads to water stress. Despite using recommended inputs to enhance yield, they are frequently unable to achieve the desired productivity due to inconsistent water availability. Although experimental studies indicate that drip irrigation can improve water productivity for horticultural crops, these results often diverge significantly from field-level findings, making them less reliable for formulating policy decisions. Furthermore, there has been little research into the economic viability of drip irrigation for short-duration crops such as brinjal, tomato, and watermelon. As a result, there is a need for large-sample studies that investigate the water-saving potential of drip irrigation and its economic feasibility.

This study seeks to address this gap by analysing data from five different horticultural crops grown across five districts in Tamil Nadu. The research has four main objectives. First, it aims to estimate the extent of water savings achieved with drip irrigation compared to conventional flood irrigation. Second, it seeks to compare the productivity of horticultural crops grown under drip irrigation with those grown using the flood irrigation method to identify any yield differences. Third, the study evaluates the income and profitability of farmers cultivating crops under drip and flood irrigation, providing insights into the financial implications of adopting drip irrigation. Finally, it aims to estimate the Net Present Value (NPV) and Benefit-Cost Ratio (BCR) of investing in drip irrigation for horticultural crops, considering both the presence and absence of capital subsidies and applying various discount rates. By focusing on these areas, the study provides valuable insights into the potential of drip irrigation to enhance water efficiency, increase crop productivity, and improve the economic well-being of farmers in Tamil Nadu.

II

STUDY AREA AND METHODOLOGY

This study was conducted in Tamil Nadu, utilizing data from farmers growing five horticultural crops—brinjal, tomato, banana, watermelon, and mango—under drip and flood irrigation. Tamil Nadu is a significant State for horticultural crop production in India, with about 5.48 per cent of the area and 6.10 per cent of the production of horticultural crops in India during 2021-22. With irrigated land shrinking due to declining water availability, farmers have increasingly adopted drip irrigation for better water management in recent years. Five districts were selected based on drip irrigation use to examine the impact of drip irrigation on water saving, crop productivity, income, and economic viability. Namakal district was chosen for brinjal, Dharmapuri for tomato, Tiruchirapalli for banana, Villupuram for watermelon, and Krishnagiri for mango cultivation. Drip irrigation has been widely adopted in these districts, enabling a detailed comparison between drip and flood irrigation.

This study analyses the impact of drip irrigation by comparing water usage, productivity, and profitability for five horticultural crops—brinjal, tomato, banana, watermelon, and mango—cultivated using drip irrigation and flood irrigation. For each crop, 100 farmers were surveyed, with 50 being drip irrigation adopters and 50 non-adopters, making a total sample size of 500 farmers (250 drip irrigation adopters and 250 flood irrigation users). In Tamil Nadu, as in other States, drip irrigation adopters typically use groundwater from wells for irrigation. To ensure consistency and eliminate the effects of irrigation sources on water consumption and crop productivity, only farmers who rely on groundwater for drip irrigation and flood irrigation were considered in this study. Farmers adopting drip irrigation were selected through random sampling, while non-adopters were chosen based on their proximity to drip irrigation adopters' fields. This was done to minimize variations in soil quality and other agro-economic factors, ensuring a more accurate comparison of drip and flood irrigation systems. The detailed field survey was conducted for the 2018-19 agricultural year, providing relevant insights into the performance of drip irrigation in terms of water savings, productivity, and profitability for these five crops under real-world farming conditions.

This study aims to assess the economic viability of investments in drip irrigation for different horticultural crops. To evaluate this, the study uses two financial metrics: Net Present Value (NPV) and Benefit-Cost Ratio (BCR), calculated using the discounted cash flow method. NPV is defined as the difference between the present value of the benefits and the present value of the costs over the lifespan of the drip system. It includes items like cost of capital and depreciation. According to the NPV criterion, an investment is economically viable if the present value of benefits exceeds that of the costs. An investment is economically viable if the BCR exceeds one (see Gittinger, 1984). By calculating NPV and BCR, this study aims to provide a comprehensive understanding of the economic returns from drip irrigation investment, helping farmers and policymakers determine whether drip irrigation is a financially sustainable option for horticultural crops.

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

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

[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 mentioned earlier, adopting drip irrigation requires fixed capital, making it essential to account for income and cost streams over the entire lifespan of the drip system. However, collecting actual cash flows for the entire lifespan is challenging due to a lack of observed long-term data on benefits and costs. Therefore, the following realistic assumptions are made to estimate cash inflows and outflows for the drip irrigation system:

1. The drip system's lifespan is assumed to be five years, as used in the INCID (1994) study, for calculating the net present value (NPV) and benefit-cost ratio (BCR) for all crops except mango. For mango, two alternative lifespans of 15 and 25 years are assumed based on farmers' experiences. NPV and BCR are estimated to have a 10-year lifespan based on feedback from drip irrigation adopters for other crops.
2. The cost of cultivation and income from the five different horticultural crops grown using drip irrigation are assumed to remain constant throughout the drip system's life.
3. To assess the sensitivity of investment to changes in capital costs, two different discount rates of 10 per cent and 15 per cent are applied, representing the opportunity cost of capital.
4. The input usage and technology for cultivating the selected horticultural crops are assumed to remain constant over the entire lifespan of the drip system.

III

RESULTS AND DISCUSSION

Several field studies on crop cultivation under drip irrigation exist in India (Saleth, 2009; Viswanathan et al., 2016). However, there is limited research on horticultural crops in Tamil Nadu, especially using large sample survey data and well-structured methodology. Since horticultural crops, particularly vegetables, are typically grown for commercial purposes with irrigation, it is important to analyze the economic and other impacts of drip irrigation on such crops. As outlined in the methodology, this study selected 500 farmers—250 drip irrigation adopters and 250 non-adopters—for a detailed analysis. Before examining the impact, the basic characteristics of the farmers are examined. The drip irrigation adopters generally exhibit better socio-economic characteristics than non-adopters (Table 1). The differences are particularly notable in education, farm size, and irrigation practices. Drip irrigation requires a significant initial investment; thus, larger farmers with better financial resources are more likely to adopt this method. This finding aligns with other studies on technology adoption, which consistently show that early adopters of new technologies tend to be better educated and more resourceful. Consequently, it was expected that wealthier and more educated farmers would initially adopt drip irrigation in horticultural crop cultivation.

TABLE 1: SELECTED CHARACTERISTICS OF DRIP AND NON-DRIP ADOPTERS CULTIVATING HORTICULTURAL CROPS

Characteristics	Brinjal		Tomato		Banana		Watermelon		Mango	
	DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI	DMI	FMI
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
Age of farmer head (in years)	50.90 (8.74)	50.98 (9.22)	45.49 (11.66)	48.94 (10.70)	47.22 (8.08)	51.20 (9.23)	45.36 (8.34)	50.26 (11.67)	49.26 (4.10)	49.84 (7.43)
Education of farmer (in years)	9.16 (2.66)	6.52 (3.28)	9.14 (3.91)	7.72 (4.48)	9.54 (4.31)	5.90 (5.22)	8.48 (4.25)	7.08 (4.09)	9.36 (2.58)	6.62 (3.99)
Farming experience (in years)	24.94 (9.29)	30.14 (10.71)	17.14 (9.27)	20.40 (9.89)	18.08 (10.83)	19.26 (8.64)	15.50 (5.18)	22.20 (8.74)	23.88 (5.37)	28.56 (8.65)
Landholding size of the household (in acres)	8.25 (2.75)	3.72 (1.94)	4.22 (2.11)	3.84 (1.31)	8.83 (3.97)	8.77 (8.78)	4.19 (2.05)	3.41 (1.84)	6.23 (2.57)	4.23 (2.21)
Net cropped area (in acres)	7.26 (3.36)	3.69 (1.89)	4.22 (2.11)	3.84 (1.31)	8.83 (3.97)	8.77 (8.78)	4.19 (2.05)	3.41 (1.84)	6.23 (2.57)	4.11 (2.10)
Well irrigated area to total irrigated area (in %)	100	100	100	100	100	78.08	100	100	100	100
Average Foodgrains area (in acres)	1.63 (1.14)	0.65 (1.25)	2.97 (2.50)	2.48 (1.21)	0.15 (0.35)	1.75 (2.18)	2.88 (1.90)	1.46 (1.53)	0.00	0.00
Foodgrain area to GCA (%)	6.68	5.19	35.70	60.73	0.57	6.96	35.94	22.54	0.00	0.00
Non-foodgrain area to GCA (%)	93.32	94.81	64.30	39.27	99.43	93.04	64.06	77.46	100	100
Cropping intensity (in %)	291	270	197	165	300	287	191	190	300	284

Source: Computed using field survey data.
Note: Figures in brackets are standard deviation.

Water Consumption and Saving:

The water use pattern differs based on the irrigation method, with drip irrigation allowing for better control of water through a pipe network compared to flood irrigation. Hence, the water used under drip irrigation will likely differ from that used in flood irrigation. To quantify this, the number of irrigations and hours of water used per irrigation were analysed for drip irrigation adopters and non-adopters across five crops. Table 2 reveals that the number of irrigations significantly exceeded that of non-drip irrigation crops. For instance, drip irrigation adopters irrigated brinjal 2.97 times more than non-adopters, 4.51 times more for tomato, and 3.49 times more for banana. Similar trends are observed for other crops. Since drip irrigation adopters irrigate based on the crops' needs, the irrigation frequency is higher. This reflects the precision and efficiency of water use in drip irrigation systems.

TABLE 2: PATTERN OF WATER USE IN FIVE HORTICULTURAL CROPS UNDER DMI AND FMI

Crop's Name (1)	Method (2)	Horsepower (HP) of pump sets (3)	Number of irrigation applied/acre (4)	Hours used per irrigation/acre (5)
Brinjal	Drip Irrigation	5.67	166.90	1.04
	Flood Irrigation	5.21	56.26	5.63
Tomato	Drip Irrigation	5.28	75.60	0.89
	FMI	6.54	16.78	6.19
	FMI	5.08	54.86	10.32
Banana	DMI	5.64	112.40	2.87
	FMI	6.05	32.20	16.14
Watermelon	DMI	5.34	74.90	0.55
	FMI	5.41	19.74	4.42
Mango	DMI	5.83	44.40	1.02
	FMI	5.92	18.58	5.40

Source: Computed using field survey data.

Despite drip irrigation adopters using more frequent irrigation for all selected crops, the hours spent per irrigation are significantly lower than those of flood irrigation users. For instance, farmers cultivating brinjal with drip irrigation used approximately 1.04 hours per irrigation, while flood irrigation users took nearly 5.63 hours. Similarly, banana farmers using drip irrigation needed 2.87 hours per irrigation, whereas non-drip irrigation users spent 16.14 hours. This difference arises because water is supplied directly to the crop's root zone, significantly reducing the time required for each irrigation cycle. In contrast, flood irrigation delivers water across the entire field, not just the crop zone, which increases the time needed. Additionally, flood irrigation involves water-conveying channels and uneven land surfaces, which require more water and time for irrigation. Evaporation losses in open water channels further prolong the irrigation time in flood irrigation. These issues are minimized or eliminated with drip irrigation, where water is delivered through a pipe network. This ensures a more efficient and targeted irrigation process, thus saving time and reducing water wastage.

Water consumption per acre is significantly lower under drip irrigation for all five crops studied. The amount of water used per acre depends on various factors, including pump horsepower (HP), water level in the well, size of delivery pipes, quality of machinery, distance between the water source and the field, soil quality, and terrain condition. Since these factors can vary widely across farms, water consumption is estimated in terms of HP hours per acre. This is calculated by multiplying the pump's HP with the hours of water use, providing a standardized measure for water consumption across different conditions.

Table 3 shows that water consumption is significantly lower under drip irrigation than flood irrigation, with savings ranging from 39 to 55 per cent. Water savings for brinjal is around 41 per cent, 39 per cent for banana, and 55 per cent for mango when comparing drip irrigation adopters to non-adopters. Among the five crops studied, mango exhibits the highest water savings. Drip irrigation eliminates evaporation and distribution losses by delivering water directly to the root zone. The targeted irrigation approach of drip irrigation significantly reduces water usage. As a result of these water savings, electricity savings are also substantial, although these are not covered in this paper due to space limitations.

TABLE 3: WATER CONSUMPTION BY DRIP AND NON-DRIP IRRIGATED HORTICULTURAL CROPS

Crops	Water Consumption (HP hour/acre)		Water Saving over FMI	
	DMI	FMI	In %	In quantity (HP hour/acre)
(1)	(2)	(3)	(4)	(5)
Brinjal	943.83	1587.60	-40.55	-643.78
Tomato	328.80	654.15	-49.74	-325.35
Banana	1476.85	2435.90	-39.37	-959.05
Watermelon	210.85	461.34	-54.30	-250.49
Mango	254.58	564.78	-54.92	-310.21

Source: Computed using field survey data.

Productivity Gains:

One of the primary reasons for adopting drip irrigation is the increased crop productivity it offers. Crop yields are often negatively impacted by moisture stress under flood irrigation, as maintaining a consistent water supply is challenging. Technical studies have shown that drip irrigation effectively eliminates moisture stress by irrigating the root zone with the required frequency and adequate water (INCID, 1994; Narayanamoorthy, 2022). Consequently, crop productivity with drip irrigation is significantly higher than flood irrigation, making it a preferred irrigation method for farmers.

Table 4 clearly shows that the productivity of all five horticultural crops is significantly higher when cultivated using drip irrigation compared to flood irrigation. The yield gap between drip and flood irrigation ranges from 33 per cent to 41 per cent. For instance, brinjal and tomato yields under drip irrigation are about 35 per cent higher than those grown with flood irrigation. In absolute terms, the yield gap between drip irrigation adopters and non-adopters is around 59 quintals per acre for brinjal and 75 quintals per acre for banana. It is important to note that despite the higher costs associated with yield-enhancing inputs like seeds, fertiliser, and electricity, the productivity of crops grown under flood irrigation remains significantly lower than those grown using drip irrigation, highlighting its efficiency.

TABLE 4: PRODUCTIVITY OF HORTICULTURAL CROPS CULTIVATED UNDER DMI AND FMI

Crops	Productivity (quintals/acre)		Yield gap	
	DMI	FMI	In per cent	In quintals
Brinjal	224.19	165.52	35.45	58.68
Tomato	138.30	101.96	35.64	36.34
Banana	261.58	186.70	40.11	74.88
Watermelon	133.20	94.20	41.40	39.00
Mango	57.28	43.18	32.64	14.10

Source: Computed using field survey data.

There are three key reasons for the higher productivity of horticultural crops cultivated using drip irrigation. First, drip irrigation ensures an adequate water supply, promoting better crop growth and, thus, higher productivity. Second, weed growth in non-crop areas is minimal under drip irrigation, unlike in flood irrigation, where weeds consume significant yield-enhancing inputs, reducing crop yields. Third, fertilizer losses through evaporation and leaching are reduced in drip irrigation, as water is delivered directly to the crop. Although non-adopters of drip irrigation incur higher cultivation costs, this does not translate into higher yields. Therefore, the increased productivity observed in the field survey can be attributed to drip irrigation.

Profitability and Viability of Drip Investments:

While drip irrigation conserves water and boosts crop productivity, it involves a higher fixed capital investment. Hence, a careful study of its economic viability with a proper methodology must inform policy decisions. Key issues that need to be addressed include (i) the impact of fixed capital on the economic viability of drip irrigation and (ii) the effect of government subsidies and varied discount rates on the economic outcomes of drip irrigation.

Table 5 details the cost of cultivation, gross income, and profit for all five crops. Only variable costs were considered for calculating profit, excluding fixed costs such as interest, discount rate, and depreciation. To estimate profit per acre, the total cultivation cost (cost A2+FL) was subtracted from the total income earned by farmers from crop cultivation. Total income per acre was calculated by multiplying the yield with the price farmers received. Since each of the five crops is grown with different space requirements, the average capital cost of the drip system varies. For instance, the average fixed capital cost of drip irrigation for banana is Rs. 44,010 per acre, whereas for mango it is Rs. 40,120 per acre without any capital subsidy (Table 6). Given the capital-intensive nature of drip irrigation, both the Central and State governments have provided subsidies to encourage its adoption since the early 1990s (FICCI, 2013, 2016). Currently, the Central government offers a 55 per cent subsidy to small and marginal farmers and 45 per cent to other farmers for drip system purchases. The average capital subsidy farmers receive in this study ranges from Rs. 22,005 per acre for banana to Rs. 28,455 per acre for watermelon, making the technology more affordable and encouraging wider adoption.

TABLE 5: RELATIVE ECONOMICS OF HORTICULTURAL CROPS CULTIVATED UNDER DMI AND FMI

Particulars	Crop's Name	DMI	FMI	Gains over FMI	
				In per cent	In Rs
(1)	(2)	(3)	(4)	(5)	(6)
1. Cost of cultivation (Rs/acre)*	Brinjal	77495	98218	-21.10	-20723
	Tomato	53158	62682	-15.20	-9524
	Banana	83665	99932	-16.28	-16267
	Watermelon	21619	26935	-19.74	-5316
	Mango	29506	38432	-23.22	-8926
2. Gross income (Rs/acre)	Brinjal	560485	413793	35.45	146692
	Tomato	235110	173332	35.64	61778
	Banana	392376	280050	40.11	112326
	Watermelon	93240	65940	41.40	27300
	Mango	85917	64774	32.64	21143
3. Profit (Rs/acre)	Brinjal	482990	315839	52.92	167151
	Tomato	181952	110650	64.44	71302
	Banana	308711	180118	71.39	128593
	Watermelon	71621	39005	83.62	32616
	Mango	56410	26341	114.15	30069

Note: * Refers to cost A2+FL.

Source: Estimated from the field survey.

TABLE 6: CAPITAL COST OF DRIP-SET FOR HORTICULTURAL CROPS, WITHOUT AND WITH SUBSIDY

Crops	Capital cost (Rs/acre)		Average
(1)	Without subsidy	With subsidy	subsidy (Rs/acre)
Brinjal	43154	17262	25892
Tomato	42008	14703	27305
Banana	44010	22005	22005
Watermelon	43777	15322	28455
Mango	40120	12036	28084

Source: Computed using field survey data.

In terms of profitability, the analysis shows that non-adopters of drip irrigation earn Rs. 1,80,118 per acre for banana, while drip irrigation adopters earn Rs. 3,08,711—an increase of 71.39 per cent. Similarly, for brinjal, drip irrigation adopters earn significantly more, with Rs. 4,82,990 per acre compared to Rs. 3,15,839 for other users. This trend holds across all other crops studied. The higher profitability is expected, as drip irrigation reduces the cost of cultivation (cost A2+FL) and substantially increases crop productivity.

However, this substantial profit difference should not be considered conclusive evidence of drip irrigation's overall advantage. The lifespan of the drip system plays a crucial role in determining long-term profitability. Since drip irrigation is a capital-intensive technology, the high initial investment required to install the system is often considered a significant barrier to widespread adoption. Is this perception accurate? Additionally, what role does government subsidy play in determining the economic viability of drip irrigation? These questions must be addressed to fully understand drip irrigation's potential for broader adoption.

Although drip irrigation adopters receive government subsidies for installing drip systems, Net Present Value (NPV) and Benefit-Cost Ratio (BCR) were calculated under both with-subsidy and without-subsidy scenarios to assess the subsidy’s role in drip irrigation adoption. Table 7 presents the estimated NPV and BCR values for all five crops under different conditions. As expected, the NPV with subsidy is slightly higher than without subsidy across all crops. For example, at a 15 per cent discount rate and a 5-year lifespan, the NPV for brinjal is Rs. 15,81,764 per acre without subsidy, increasing to Rs. 16,04,279 per acre with subsidy. Similarly, for banana, the NPV is Rs. 9,96,578 per acre without subsidy, rising to Rs. 10,07,696 per acre with subsidy. This indicates that the subsidy provides substantial additional benefits to drip irrigation adopters, encouraging the cultivation of horticultural crops. Thus, subsidies play a crucial role in enhancing the economic viability of drip irrigation systems.

The Benefit-Cost Ratio (BCR), like the Net Present Value (NPV), shows notable differences when calculated with and without capital subsidies and across varying lifespans of drip irrigation systems. The BCR with subsidy is consistently higher for all five crops. For example, in brinjal, with a 5-year drip system lifespan and no subsidy, the BCR is 6.32 at a 15 per cent discount rate. However, with a subsidy, it increases to 6.84. Similarly, the BCR without subsidy for bananas is 4.13 at a 15 per cent discount rate and a 5-year lifespan, while it rises to 4.28 with the subsidy. The BCR improves significantly

TABLE 7: NET PRESENT VALUE AND BENEFIT-COST RATIO OF DRIP-IRRIGATED HORTICULTURAL CROPS

Crop's name (1)	Subsidy category (2)	Life period (years) (3)	Discount rate (per cent) (4)	NPV (Rs/acre) (5)	BCR (6)
Brinjal	With subsidy	5	15	1604279	6.84
			10	1815482	6.87
		10	15	2409352	6.97
			10	2952497	7.01
	Without subsidy	5	15	1581764	6.32
			10	1791943	6.39
		10	15	2386837	6.60
			10	2928958	6.69
Tomato	With subsidy	5	15	597148	4.13
			10	676377	4.15
		10	15	900392	4.22
			10	1104653	4.25
	Without subsidy	5	15	573404	3.67
			10	651554	3.72
		10	15	876648	3.89
			10	1079830	3.96
Banana	With subsidy	5	15	1007696	4.28
			10	1141188	4.30
		10	15	1518213	4.37
			10	1862197	4.39
	Without subsidy	5	15	996578	4.13
			10	1130249	4.16
		10	15	1511081	4.30
			10	1856888	4.35
Watermelon	With subsidy	5	15	226761	3.64
			10	257570	3.69
		10	15	346125	3.84
			10	426150	3.90
	Without subsidy	5	15	202017	2.83
			10	231702	2.90
		10	15	321381	3.19
			10	400282	3.32
Mango	With subsidy	15	15	319386	2.75
			10	418120	2.78
		25	15	354179	2.76
			10	501097	2.80
	Without subsidy	15	15	294965	2.42
			10	392589	2.50
		25	15	329758	2.46
			10	475567	2.56

Source: Computed using field survey data.

for all crops, calculated with a 10 per cent discount rate and a 10-year drip system lifespan. The same trend is observed in the mango crop, where the lifespan of the drip system is alternatively considered as 15 and 25 years. These results highlight the positive role of government subsidies in enhancing the economic viability of drip irrigation for all selected crops. However, even without subsidies, the BCR calculations at both 10 per cent and 15 per cent discount rates show that drip irrigation investments are economically viable for farmers. An essential question for farmers and banks is how many years it takes to recover the fixed capital costs of drip irrigation. Year-wise NPV estimates suggest that farmers can recover the entire fixed capital cost of the drip system in the first year, indicating that drip irrigation can offer a quick return on investment, even without subsidies.

IV

CONCLUSION AND RECOMMENDATIONS

This study explores whether adopting drip irrigation can enhance the productivity and income of farmers cultivating five different horticultural crops in five districts of Tamil Nadu. The findings indicate drip irrigation can significantly conserve water and boost crop productivity and farmer income. Water savings for the five crops studied range from 39 per cent to 55 per cent compared to conventional flood irrigation. Drip irrigation has significantly increased the yield of these crops by minimizing moisture stress. The yield gap between drip and non-drip irrigated crops varies from 32.64 per cent for mango to 41.40 per cent for watermelon.

The reduced cost of cultivation combined with increased productivity has resulted in higher profits for farmers using drip irrigation. Profit increases for drip irrigation users range from 52.92 per cent in brinjal to 114.50 per cent in mango compared to those using flood irrigation. The Net Present Value (NPV) and Benefit-Cost Ratio (BCR), calculated using the discounted cash flow method, demonstrate that drip irrigation is economically viable for all horticultural crops, even without subsidies.

The study suggests that adopting drip irrigation for horticultural crops could bring substantial benefits to farmers. Inadequate water supply through flood irrigation is a major challenge for farmers in Tamil Nadu and across India. This impending water shortage could disproportionately affect smallholders, who are key producers of vegetable crops. Therefore, expanding the adoption of drip irrigation can alleviate the water stress farmers face and significantly improve their incomes.

Despite these benefits, the adoption of drip irrigation remains limited relative to its potential. The Task Force on Micro-Irrigation estimated that India has a potential of 27 million hectares (mha) for drip irrigation and 69.5 mha for sprinkler irrigation. Currently, drip irrigation covers only 6-7 mha nationwide. While both Central and State governments have implemented various programmes to enhance agricultural productivity, they should consider allocating some funds to promote cultivating horticultural crops—especially vegetables—under drip irrigation.

Although horticultural crops are grown across many States, most farmers remain unaware of the significant benefits drip irrigation offers in terms of increased productivity and reduced water usage. The lack of awareness about drip irrigation's advantages is the main reason for its limited adoption. Systematic efforts are needed to promote drip irrigation adoption through continuous awareness campaigns, including special broadcast programmes that highlight the economic and environmental benefits of this irrigation method.

Given the increasing water scarcity in India, partly due to climate change, policymakers should prioritize policies and programmes that promote efficient water use in agriculture. Drip irrigation offers a sustainable solution to the challenges posed by dwindling water resources by increasing productivity per unit of water. Expanding the use of drip irrigation will not only address water scarcity but also help smallholders improve their incomes and improve the overall sustainability of the agricultural sector. Policymakers must focus on generating more crop output per drop of water, ensuring a sustainable future for Indian agriculture.

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