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Adoption of Drip Irrigation System in India: Some Experience and Evidence

D. SURESH KUMAR*

In recognition of the importance of drip irrigation, the paper addresses two important issues: factors limiting or enhancing the adoption of drip irrigation systems, and policy actions needed at different levels to speed up the adoption of drip irrigation and groundwater development. The drip method of irrigation is found to have a significant impact on resources saving, cost of cultivation, yield of crops and farm profitability. The adoption of drip irrigation is significantly influenced by experience, farm size, proportion of wider spaced crops and participation in non-farm income activities. The policies should focus on promotion of drip irrigation in those regions where scarcity of water and labour is severe and where shift towards wider-spaced crops is taking place.

Key words: Adoption, Drip irrigation, Double difference method, Factors influencing adoption, Non-adopters

JEL Classification: Q15, Q16, Q18

I. INTRODUCTION

Water is becoming an increasingly scarce resource and limiting agricultural development in many developing and developed economies across the world. A study by the International Water Management Institute (IWMI) shows that around 50 per cent of the increase in demand for water by the year 2025 can be met by increasing the effectiveness of irrigation (Seckler *et al.* 1998). In India, almost all the easily accessible and economically viable irrigation water potential has already been developed, but the demand for water for different sectors has been growing continuously (Saleth 1996, Vaidyanathan 1999). Moreover, the water use efficiency in the agricultural sector, which still consumes over 80 per cent of water, is only in the range of 30-40 per cent in India, indicating that there is considerable scope for improving the water use efficiency.

The review of past studies shows that the solution to the problem of growing groundwater scarcity and persistent groundwater resource degradation across

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* Associate Professor, Department of Agricultural Economics, Tamil Nadu Agricultural University, Tamil Nadu, India.

regions are two fold: Firstly, the supply side management practices like watershed development, water resources development through major, medium and minor irrigation projects. The second is through the demand management by efficient use of the available water both in the short-run and long-run perspectives. This includes drip irrigation and other improved water management practices. Recognising the importance of sustainable water use efficiency in agriculture, a number of demand management strategies (like water pricing, water users association, turnover system, etc.) have been introduced since the late 1970s to increase the water use efficiency, especially in the use of surface irrigation water.

One of the demand management mechanisms is the adoption of micro irrigation such as drip and sprinkler method of irrigation. Evidence shows that many researchers attempted to study the impact of drip irrigation (Narayanamoorhty 1997, Qureshi *et al.* 2001, Namara *et al.* 2005, Kulecho and Weatherhead 2005, Narayanamoorthy 2003, Dhawan 2002, Verma *et al.* 2004, Magar *et al.* 1988, Cuykendall *et al.* 1999). The water use efficiency increases up to 100 per cent in a properly designed and managed drip irrigation system (INCID 1994, Sivanappan 1994). Drip method of irrigation helps to reduce the over exploitation of groundwater that partly occurs because of inefficient use of water under surface method of irrigation. Environmental problems associated with the surface method of irrigation like water logging and salinity are also completely absent under drip method of irrigation (Narayanamoorhty 1997). In addition, drip method helps in achieving saving in irrigation water, increased water use efficiency, decreased tillage requirement, higher quality products, increased crop yields and higher fertiliser use efficiency (Qureshi *et al.* 2001, Sivanappan 2002, Namara *et al.* 2005).

Though the potential benefits generated by the drip irrigation methods are apparent, the adoption of drip irrigation is yet to be widely promoted across regions, states and elsewhere. Kumar (2005) found that the most ideal policy environment for promotion of micro irrigation technologies in well irrigated areas would be pro-rata pricing of electricity, while this would create direct incentive for efficient water use. Adoption of micro irrigation systems is likely to pick up fast in arid and semi arid, well-irrigated areas, where farmers have independent irrigation sources, and where groundwater is scarce. Further, high average land holdings, large size of individual plots, and a cropping system dominated by widely spaced row crops, which are also high-valued, would provide the ideal environment for the same (Kumar *et al.* 2008).

The factors such as huge initial investment, small size of holding, lack of technical support, cropping pattern, access to water and socio-economic conditions of farmers, etc. (Namara *et al.* 2005) are found to the major factors influencing adoption of drip irrigation. In some cases, even after the adoption of drip irrigation, the farmers, particularly the small farmers, found to discontinue drip irrigation for several reasons such as lack of maintenance, irrelevant cultural background, and unreliable water supply (Kulecho and Weatherhead 2005). Though there are many studies attempted to identify factors limiting the adoption of drip irrigation, still, it is not clear where should we promote micro irrigation.

In this context, the drip irrigation has received much attention from policy makers and others for its perceived ability to contribute significantly to groundwater resources development, agricultural productivity, economic growth, and environmental sustainability. Yet in many parts of the country and elsewhere, they have yet to be widely adopted. Also, it is crucial to determine/locate the areas where the micro irrigation should be encouraged and promoted. Keeping these issues in view, the present paper has addressed the following important issues: (i) what changes the drip irrigation brings to the farming system?, (ii) whether the adoption of drip irrigation is motivated by the cropping pattern or the cropping pattern is followed by drip adoption?, (iv) what factors limit/enhance the adoption of drip irrigation systems? and (ii) What policy actions must be taken at different levels to speed up the adoption of drip irrigation and groundwater development?.

II. METHODOLOGY AND SOURCES OF DATA

2.1 The Data

The study was conducted in the Coimbatore district of Tamil Nadu, India where groundwater resource degradation is alarming. Two blocks were selected so as to represent drip adoption and control. From the selected blocks, two villages were selected purposively where the adoption of drip irrigation is widespread. Farm households in the selected villages constituted the sample units. To examine the adoption and impact of drip irrigation on resource use, agricultural production and farm income, 25 drip-adopting farmers were selected in each village and correspondingly 25 non-drip adopters were selected in control villages. To select the drip adopters, the list of farmers from the Department of Agricultural Engineering was collected. Also, we enumerated the list of farmers adopting drip irrigation after discussions with the villagers and private firms dealing with drip irrigation systems. Thus, a sample of 100 farmers was studied.

For the purpose of the study, interview schedules were formulated and pre-tested. The needed information from the respondent group was gathered personally administering the interview schedule. The primary information collected from the farm households included details on well investment, groundwater use, extraction and management, crop production including input use and output realised, farm income, adoption of drip irrigation, and investment on drip irrigation. This also included asset position, education and other socio-economic conditions.

2.2 Quantification of Benefits and Double Difference Methodology

Farm level data were collected for both drip adopters and non-adopters before and after drip irrigation technology. This enables the use of the double difference method to study the impacts due to adoption of drip irrigation. The framework was adopted from the program evaluation literature (Maluccio and Flores 2005).

2.3 Adoption of Drip Irrigation

A key concern for policy makers is making the farm households adopting micro irrigation technologies in order to address the growing groundwater scarcity. Thus, an important research question is what factors influence farm households' decision to adopt drip irrigation. For the purpose, area under drip irrigation installed by the farm households was considered as the dependent variable. It is expected that the adoption of drip irrigation by the farm households is influenced by different physical, socio-economic, institutional and household specific factors.

The dependent variable adoption of drip irrigation would be zero for those households who do not adopt drip irrigation. If the dependent variable is censored, values in a certain range may all be recorded as single value. Given that our dependent variable is censored at zero, a Tobit estimation rather than OLS is appropriate (Madalla 1989, Tobin 1958). In such a case, Tobit estimators may be used. Thus, the functional form of the model specified in the present study with a Tobit model, with an error term (Ui) which is independently, normally distributed with zero mean and constant covariance, is

$$
\begin{aligned}
DA^{*}i &= Xi\,b + Ui \\
DAi &= T^{*}i \quad \text{if} \quad Xi\,b + Ui > 0 \\
&= 0 \quad \text{if} \quad Xi\,b + Ui <= 0 \\
& \quad i = 1....n
\end{aligned}
\qquad (1)
$$

where,

DAi = Area under drip irrigation in hectares

Xi = Vector of independent variables

b = Vector of unknown coefficients

n = Number of observations

In the above functional relationship, the DAi is the endogenous variable which is expected to be influenced by other exogenous variables viz., age of the farmer in years (AGE), educational level of the farmer in years of schooling (EDUCATION), farm size in hectares (FSIZE), proportion of wider spaced crop (WIDERCROP), participation in non-farm income activities (NONFARM) and percentage of area irrigated by wells (AWELLS).

Economic implications can be drawn by using the results of the empirical model. Following a Tobit decomposition framework suggested by McDonald and Moffitt (1980), the effects of the changes in the explanatory variables on the probability of adoption of drip irrigation and intensity of adoption could be obtained.

The basic relationship between the expected value of all observations, E(DA), the expected value conditional upon being above the limit, $E(DA^*)$, and the probability of being above the limit, F(z), is

$$E(DA) = E(DA^*).F(z) \tag{2}$$

The effect of a given change in the level of the explanatory variables on the dependent variables can be obtained by decomposing the equation (2) is,

$$\frac{\partial E(DA)}{\partial X_i} = F(z)\left(\frac{\partial E(DA^*)}{\partial X_i}\right) + E(DA^*)\left(\frac{\partial F(z)}{\partial X_i}\right) \tag{3}$$

Thus, the total elasticity of change in the level of the explanatory variable consists of two effects: (i) change in DA of those above the limit (i.e. elasticity of intensity of drip adoption, for those households who already an adopter) and (ii) the change in the probability of being above the limit (i.e. probability of drip adoption).

III. STUDY AREA

Tamil Nadu state ranks seventh in the country in terms of area under micro irrigation. During 2008, a total area of 158,521 ha was practiced under micro irrigation in the Tamil Nadu state. Of the total area under micro irrigation, the drip accounted for 82.85 per cent (131,335 ha) and sprinkler for 17.15 per cent (27,186 ha). At the national level, the area under drip irrigation was 36.82 per cent and under sprinkler was 63.18 per cent. It is clear that the drip method of irrigation is more popular among the farmers in Tamil Nadu when compared to sprinkler method of irrigation. It is seen that the Tamil Nadu state has only 9.2

per of the total drip irrigated area in the country, whereas the sprinkler irrigation accounts for only 1.1 per cent. The area under micro irrigation accounts for 4.1 per cent of the total area under irrigation in the country. The area under micro irrigation is very low in Tamil Nadu when compared to the national level area. The net sown area of the state is 51.3 lakh ha, whereas the gross cropped area is 58.4 lakh ha. The area under micro irrigation accounts for only 3.1 per cent of the net sown area of the state, whereas it accounts for 5.5 per cent of the net irrigated area and 4.8 per cent of the gross irrigated area. Thus, there is a huge potential to increase the area under micro irrigation in the state.

In the study area, i.e. the Coimbatore district of Tamil Nadu state, agriculture depends largely on minor irrigation projects and other sources such as wells, rainfed tanks, etc. The chief source of irrigation in the district is through wells. The average well-failure rate is 47 per cent for open-wells and 9 per cent for bore-wells. There are six different soil types viz., red calcareous soil, black soil, red non-calcareous soil, alluvial and colluvial soil, brown soil and forest soil. The mean annual rainfall for the 45 years (between 1961 and 2005) is 687.1 mm and the coefficient of variation is estimated to be 28.2 per cent. The distribution of rainfall across seasons indicates that the mean rainfall ranged from 16 mm during winter to 348 mm during north-east monsoons. The groundwater potential as on January 2003 indicated that the total groundwater recharge was 880.97 million cubic meter (MCM), net groundwater availability (90 per cent of total groundwater recharge) was 792.87 MCM, domestic and industrial draft was 40.57 MCM, irrigation draft was 779.13 MCM and the stage of groundwater development was 103 per cent.

The level of groundwater development exceeds 100 per cent of the utilisable groundwater recharge in eleven blocks, between 90 and 100 per cent in four blocks and between 70 and 90 per cent in another four blocks. The stages of groundwater development in the study blocks, viz. Anamalai and Madathukulam blocks was 51 per cent and 56 per cent, respectively. Increasing private investment on wells is visualized over the years as groundwater irrigation assumes importance. Farmers in this district rely heavily on groundwater for irrigation.

Dependence on groundwater for irrigation is a common phenomenon in both the study blocks. The source wise area irrigated indicates that the groundwater irrigation accounts 52.3 per cent in Annamalai block and 35.8 per cent in Madathukulam block. The increasing trend in groundwater irrigation further confirms heavy dependence on this for irrigation. This highlights the importance of groundwater for agricultural crop production i.e. the area irrigated by different abstraction structures is much more than that of the surface water sources. The irrigation system often suffers due to inadequate supply of surface water and depends upon groundwater sources as an alternative to supplement surface water to stabilise the irrigation.

IV. RESULTS FROM FIELD STUDIES

4.1 General Characteristics of the Farm Households

The general characteristics of the sample farm households were analysed. Here our aim was to observe any significant changes in land holdings, cropped area, irrigated area due to the introduction of drip irrigation. For the purpose, the drip adopters are compared with control households. It could be seen that the average size of holding among the drip adopters is significantly large when compared to non-adopters in control village. Since drip method of irrigation involves huge initial investment, large farmers adopt widely when compared to small and marginal farmers (Table I).

TABLE I
GENERAL CHARACTERISTICS OF SAMPLE HOUSEHOLDS

Particulars	Drip adopters		Non-adopters	
	Before	After	Before	After
Number of farm households	50		50	
Number of workers in the household (Number)	2.0	2.0	2.52	2.52
Farm size (Hectares)	16.54***	16.54	5.06	5.06
Net sown area (Hectares)	13.27***	14.49	4.66	4.66
Gross cropped area (Hectares)	13.71***	14.91	4.66	4.66
Cropping intensity (%)[a]	102.04**	101.82	100.00	100.00
Net irrigated area (Hectares)	13.17***	14.41	4.57	4.57
Gross irrigated area (Hectares)	13.67***	14.85	4.57	4.57
Irrigation intensity (%)[b]	102.30	101.88	100.00	100.00
Percentage of area irrigated by wells to the total cropped area (%)	99.82	99.74	97.53	97.53
Percentage of area irrigated under drip to gross cropped area (%)	96.72		..	..
Percentage of area irrigated under drip to gross irrigated area (%)	96.94		..	..

Source : Field survey during 2007-2008.

Notes: ***, ** and * indicate values are significantly different at 1 %, 5 % and 10% levels from the corresponding values of control village.

a : Cropping intensity is defined as the ratio of gross cropped area to net sown area and expressed as percentage.

b : Irrigation intensity is the ratio of gross irrigated area to net irrigated area and expressed as percentage.

The details regarding before drip adoption was collected based on the recall basis. For control villages, the reference period for the pre-adoption was considered to be 10 years before i.e. 1995.

It is argued that drip irrigation increases cropped area and area under irrigation as it is a viable water saving technology. Our study confirms the earlier findings that the drip irrigation technology increased the net sown area, net irrigated area and thereby helps in achieving higher cropping intensity and irrigation intensity. For instance, the net sown area is increased from 13.27 hectares to 14.49 hectares, whereas the gross cropped area increased from 13.71 hectares to 14.91 hectares (Table I). Similarly, the net irrigated area and gross irrigated area also increased after drip adoption. During the survey, we found that drip irrigation technology resulted in significant impacts. Being an efficient water saving technology, it helps in expanding the irrigated area and saving water.

Cropping Pattern

An attempt was made to find whether drip irrigation had induced a certain new cropping system or the crops had followed drip technology as a response to the growing water scarcity. The cropping pattern, i.e. proportion of area under different crops, is a good indicator of the development of resource endowments and agricultural production. It is expected that drip method of irrigation helps in the development of water resource potential and also helps the farmers to get more crop and income per unit of water.

The longitudinal analysis of cropping pattern across farm households and villages revealed that the adoption of drip irrigation is motivated by many factors. The two major constraints limiting agricultural production are human labour and water scarcity. These made the farmers to alter their cropping pattern towards less labour and water intensive crops. Resource poor farmers go in for rainfed crops. However, the big farmers who have access to capital adopt various water management and coping strategies. One of the important coping strategies or rather efficient water management technologies is adoption of drip irrigation. Thus, in regions where there is severe water and labour scarcity, first there is a shift from labour and water intensive crops such as vegetables, sugarcane, cotton, paddy to less labour intensive crops such as coconut, takes place and followed by drip adoption. As drip irrigation saves human labour substantially by reduction in operations such as irrigation and weeding, water loving crops such as banana and grapes are planted followed by drip irrigation.

Significant changes in cropping pattern are observed. It is evident that over a period of time, the water and labour intensive crops like paddy, sugarcane and vegetables area were significantly reduced in drip village. However, the area under coconut has increased from 45 per cent to 88 per cent over time (Table II). Increase in area under coconut is also seen among the non-adopters in the control village implying changes in the cropping pattern. Thus, the micro irrigation could be promoted in regions with high water and labour scarcity. As cropping pattern dictates the adoption and suitability of drip irrigation, widespread adoption of micro irrigation could be promoted in the regions where shift towards crops like coconut, banana are common.

TABLE II
DRIP IRRIGATION AND CROPPING PATTERN CHANGES

(Per cent)

Crops	Drip adopters		Non-adopters	
	Before	After	Before	After
Banana	9.54	**1.89**	34.24	
Turmeric	6.71	0.21	-	1.67
Paddy	6.47	1.02	35.41	13.5
Maize	-	0.87	3.82	2.2
Cotton	-	-	2.67	-
Sugarcane	5.7		22.08	17.85
Coconut	45.04	**88.63**	-	64.2
Vegetables including tomato	26.54	7.38	1.78	0.58

Source: Field Survey 2007-2008.

4.2 Irrigation Investment and Distribution of Pump Horse Power

Growing groundwater scarcity coupled with cheaper power supply resulted in further degradation of the groundwater resource in the water scarce regions like Coimbatore. It is argued that cheaper pricing policies of electricity and shifting of tariff from pro-rata[1] to flat rate[2] have reduced the marginal costs of water as well as electricity to zero. As a result, farmers use both groundwater and electricity inefficiently. The effect of such cheaper electricity has resulted in negative externalities such as over pumping, changes in crop pattern towards

[1] Pro-rata method was commonly used in most of the states till the late 1970s. In this method, farmers have to pay electricity cost based on the consumption of electricity kwh. Tariff rate sometime varies with farmers' category and horse power of pumpsets. In this method, farmers who use more electricity will have to pay more cost for electricity and vice-versa.

[2] After the 1980s, many states started to introduce flat rate system for agriculture. In this FR, tariff charges will be fixed based on the HP of pumpsets and not by the quantity of electricity consumption. Pumpset owning farmers can consume electricity as much as they need. Farmers need not pay tariff for every month. Normally it will be remitted once in three months/six months. Studies found that flat rate tariff policy has strong equity and poverty alleviation benefits. It reduces the working costs of State Electricity Boards which spend considerable amount of money for meter reading, etc. It also allows the bore well owning farmers to sell water in a low price for the poor non-bore well farmers.

more water intensive crops, well deepening, increase in well investments, pumping costs, well failure and abandonment and out migration which are increasing at a much faster rate. To cope up with the degradation of groundwater resource, farmers make huge investments on groundwater extraction. They include investment on drilling new bore wells or dug wells, deepening of existing wells, construction of intermediate storage structures and micro irrigation technologies like drip irrigation, sprinkler irrigation and so on. Thus, the investment on irrigation structures assumes crucial to study. The total amortised cost of irrigation investment is worked out as the sum of amortised cost on wells, electric motor and equipment, surface storage tanks and drip irrigation equipment.[3]

The analysis on well and irrigation investments revealed that the total fixed cost on wells and other irrigation structures is worked out to be high among the drip adopters than the non-adopters in the control village. For instance, the total amortised cost is worked out to be Rs.932 per hectare for drip adopters and Rs.5,788 per hectare for the control village. It is 61 per cent higher than that in the control village (Table III). The increased investment on fixed irrigation investments is mainly due to additional investment on drip equipments.

Of the total fixed investments, the investment on wells assumes major share. The per cent share of wells to the total cost is 39.38 per cent for drip adopters and 57.44 per cent for control farmers. It is evident that the investment on wells is higher among the control farmers. The per cent share of drip investments is calculated to be 35.7 per cent implying huge investment on drip irrigation.

Growing water scarcity coupled with low discharge rate forced the farmers to construct an intermediate water storage structures. These farm surface storage tanks help the farmers to store water and irrigate when and where needed. The water is pumped from very deep borewell and stored in these tanks and then used for irrigating crops. These storage structures are constructed by both the drip adopters and non-adopters. As the cost of construction of surface storage tank is

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[3] The amortization of irrigation structures as follows:

Amortized cost of well = [(Compounded cost of well) $*(1+i)^{AL} * i] \div [(1+i)^{AL}-1]$

Where

AL = Average life of wells

Compounded cost of well = (Initial investment on well)* $(1+i)^{(2008\text{-year of construction})}$

The discount rate of five per cent is used in amortization reflecting long term sustainable rate. Similarly, investment on conveyance, pumpset, electrical installation, and surface storage tanks and drip irrigation structures was amortized. Where AL is average life of wells and it is assumed to be 30 years based on the average life of well life in the study area. Similarly, the average life of borewells is assumed as 20 years, electrical motors 15 years, surface storage tanks 25 years and drip irrigation equipment 10 years.

very low (Rs.30–42/M^3), it is becoming popular among the farmers. These structures account for ranging between 0.6 per cent and 2.71 per cent.

TABLE III
DETAILS OF WELL AND IRRIGATION INVESTMENT IN THE SAMPLE FARMS

(Rupees/hectare of GCA)

Particulars	Drip adopters	Non-adopters
Investment on wells	3672.75*** (39.38)	3324.99 (57.44)
Investment on electric motors	2271.60 (24.36)	2306.65 (39.85)
Investment on surface storage tanks	54.73*** (0.59)	157.07 (2.71)
Investment on drip irrigation equipment	3326.83 (35.67)	..
Total investment on irrigation structures	9325.91*** (100.00)	5788.71 (100.00)
Distribution of horse power of pump		
HP/pump	5.23	6.29
HP/GCA	4.45	4.50
HP/GIA	4.45	4.65

Source: Field Survey 2007-2008.
Notes: Figures in parentheses indicate percentage to total.
*** indicates values are significantly different at 1% level from the corresponding values of control village.

4.3. Yield of Crops and Productivity Gains

Micro irrigation in general and drip irrigation method in particular are used primarily for increasing the water use efficiency. The yield of important crops grown in the sample farms is presented in Table IV. In the study area, the drip method of irrigation is followed widely in banana, coconut, and in few cases, drip adoption is followed in maize and turmeric. As the focus of this study is impact of drip irrigation, the yield of drip adopted crops is compared with the flood method. The yield of banana is worked out to be 605 qtls/hectare when compared to 591 qtls/ha in the control farmers, accounting for 2.38 per cent increase in yield under drip method over flood method of irrigation. Similarly, the coconut registered an increase in yield of 19.8 per cent under drip over flood method of irrigation. The findings of our study further confirm increased productivity could be achieved through drip method of irrigation and on line with the earlier studies (INCID 1994, Narayanamoorthy 2005, 2008). This higher crop productivity under drip method of irrigation occurs mainly through higher water use efficiency. The drip method of irrigation, unlike flood method, supplies water continuously at regular intervals, and the crops cultivated under drip method do not face moisture stress, the major factor negatively affecting crop yield (Sivanappan, 1994). Thus, drip method of irrigation significantly contributed to achieving higher yield.

TABLE IV
YIELD OF SELECT CROPS IN THE STUDY FARMS

(Quintals/hectare)

Crops	Drip adopters	Non-adopters
Banana	605.6***	591.5
Coconut[Ψ]	23012.8***	19213.5
Maize	..	33.4
Turmeric	..	50.3
Sugarcane	..	110.7
Paddy	54.5	55.7

Source: Field Survey 2007-2008.
Notes: Ψ : Number of nuts per hectare of coconut garden.
*** indicates values are significantly different at 1% level from the corresponding values of control village.

4.4 Impact of Drip on Agricultural Production

The economics of banana cultivation revealed that the cost of labour significantly reduced under drip method (Rs.11123.4/ha) which is 55.6 per cent less than that of the control village (Rs.25075.4/ha). The drip method of irrigation saves significantly the human labour involved in crop production activities. It saves irrigation labour and weeding labour. On an average the human labour days used for weeding banana is 17 labour days/ha under drip method of irrigation, whereas it is 60 labour days/ha under flood method of irrigation. Thus, the drip method saves nearly 71 per cent of weeding labour when compared to flood method of irrigation. Similarly, the drip method saves considerable labour for irrigation. The irrigation labour is worked out to be 168 labour days/ha under flood method of irrigation, whereas it is 18 labour days under drip method of irrigation. As the drip method saves considerable human labour, the cost of cultivation is significantly less under drip method over the flood method (Table V).

TABLE V
ECONOMICS OF CROP PRODUCTION FOR BANANA IN SAMPLE FARMS

(Per hectare)

Particulars	Drip adopters	Non-adopters
Quantity of water pumped (M^3)	8506.3	21316.9
Quantity of energy consumed (kwh)	2670.9	7313.9
Cost of labour (Rs.)	11123.4***	25075.4
Capital (Rs.)	70678.3***	94752.2
Yield (quintals)	605.6	591.5
Gross income (Rs.)	259937.5	254230.8
Gross margin (Rs.)	189259.2***	159478.5
Yield per unit of water (Kg/M^3)	7.1***	2.8
Yield per unit of energy (Kg/kwh)	22.5***	8.3
Returns per unit of water (Rs/M^3)	21.8***	7.6
Returns per unit of energy (Rs/kwh)	68.1***	22.9

Source: Field Survey 2007-2008.
Note: *** indicates values are significantly different at 1% level from the corresponding values of control village.

The reduction in cost towards human labour has significant bearing on the cost of cultivation. Though the cost of installation of drip equipment and maintenance is incurred by the drip farms, the reduced cost of cultivation is observed to be 25 per cent. The gross margin per hectare is calculated to be Rs. 189259.2/ha in drip farms, whereas it is Rs.159478.5/ha in control village. It clearly shows that drip method of irrigation resulted in an increase of gross margin by 18.67 per cent. As the adoption of drip irrigation saves considerable water and energy, the water and energy productivity is significantly more in drip farms than the control village where the flood irrigation is followed. For instance, the water productivity is estimated to be 7.1 kg/M^3 of water in drip farms and 2.8 kg/M^3 of water in control village. Significant difference in energy productivity is also noticed. The returns per unit of water and energy used show that drip farms have significantly higher returns as compared to those in the control village. Thus it appears that the drip adoption would be a viable technology and has significant bearing on the private profitability.

The economics of coconut cultivation in drip and control village revealed that the cost saving due to reduction in labour is as high as 63 per cent (Table VI). Similarly, the cost of cultivation has also reduced under drip method registering a decline of 9.1 per cent. It is interesting to note that the drip method resulted in high water and energy productivity.

TABLE VI
ECONOMICS OF CROP PRODUCTION FOR COCONUT IN SAMPLE FARMS

(Per hectare)

Particulars	Drip adopters	Non-adopters
Quantity of water pumped (M^3)	13185.5	21584.7
Quantity of energy consumed (kwh)	905.2	5774.9
Cost of labour (Rs.)	4670.1***	12463.5
Capital (Rs.)	29814.4***	32798.3
Yield ('00 nuts)	231.8***	199.4
Gross income (Rs.)	113737.3	85084.2
Gross margin (Rs.)	83922.8	66145.8
Yield per unit of water (nuts/M^3)	1.8***	1.0
Yield per unit of energy (nuts/kwh)	25.9***	3.8
Returns per unit of water (Rs/M^3)	6.5***	3.4
Returns per unit of energy (Rs/kwh)	95.5***	12.6

Source: Field Survey 2007-2008.
Note: ***, ** and * indicate values are significantly different at 1 %, 5 % and 10% levels from the corresponding values of control village.

The analysis of economics of crop cultivation under drip and flood methods revealed that the drip method of irrigation has significant impact on resources saving, cost of cultivation, yield of crops and farm profitability. The physical water and energy productivity is significantly higher in drip method of irrigation compared to the flood method of irritation.

4.5 Factors Influencing Adoption of Drip Irrigation

One of our main objectives was to identify the factors that influence the adoption of drip irrigation. Estimation of the factors that determine adoption of drip irrigation is presented in Table VII. The sample includes 100 farmers including the drip adopters and non-adopters in the drip and control village respectively. It can be seen that the variables AGE, FSIZE, WIDERCROP and NONFARM are found to be significant determinants of adoption of drip irrigation in both the water scarce and surplus regions. These variables are robust in determining the adoption and extent of drip adoption across regions.

TABLE VII
FACTORS INFLUENCING ADOPTION OF DRIP IRRIGATION

Variables	Regression Coefficient	Elasticity of Intensity of adoption	Elasticity of adoption
Constant	- 38.909		
	(-0.984)		
Age	0.179*	1.5817	1.6015
	(1.967)		
Education	- 0.0427		
	(-0.247)		
Fsize	0.779***	1.4461	1.4642
	(7.636)		
Widercrop	0.179**	2.6576	2.6910
	(2.428)		
Nonfarm	4.838***	0.4323	0.4377
	(2.840)		
Awells	0.242		
	(0.612)		
Log-likelihood function	- 185.00		
Number of observations	100		
Dependent variable	DAREA		
Model	TOBIT		

Source: Field Survey 2007-2008.
Notes: *** significance at 1 % level; ** significance at 5 % level; * significance at 10 % level. Figures in parentheses indicate estimated ‘t’ values.

Age of head of the household or decision making farmer influences the adoption of drip irrigation positively. The age which reflects the experience in farming has significant bearing on adoption of various agricultural crop production technologies. Experience improves awareness about the positive externalities generated by drip irrigation and motivates farmers to initiate action. Our results confirm that the experience in farming significantly influences the drip adoption.

The size of the farm reflects the wealth status of the farmers which is expected to influence drip irrigation positively as drip involves huge initial investment. We found that size of the farm exerts a significant and positive influence on adoption of drip irrigation. The reason for this may have to do with the fact that the wealthier people have adequate capital which enables them to adopt any technology, particularly the drip technology. However, a few small and marginal farmers also show inclination towards adoption of drip irrigation. But due to lack of initial investment they do not opt for drip irrigation.

Cropping pattern in any region has significant bearing on the adoption of drip technology. It is known that drip technology is more suitable when the cropping pattern is dominated by wider spaced crops such as banana, coconut, grapes and so on. Though we recommend the drip technology for the annual crops like vegetables, turmeric, sugarcane, maize, etc. drip method of irrigation is quickly adopted in regions where cropping pattern is dominated by horticultural crops like banana, grapes, etc. It is clear from the analysis that the proportion of wider spaced crop is found to be significantly influence the drip adoption. In our study area, the farmers prefer to grow less labour intensive crops like coconut and banana. This change in cropping pattern again motivates the farm households to adopt drip technology.

One can expect that participation in non-farm income activities enable the households to generate additional income to manage both their households and make adequate investments on farm development. It is evident that the variable NONFARM is found to be significantly and positively influence the drip adoption.

The proportion of area under wider space crops has the highest impact on both the adoption and intensity of adoption, followed by AGE, FSIZE and NONFARM. The total elasticity for the variable WIDERCROP is estimated to be 5.3486 which are decomposed into 2.6910 for adoption and 2.6576 for intensity of adoption. This suggests that a 10 per cent increase in area under wider spaced crop is expected to result in about 53 per cent increase in adoption of drip technology and extent of drip irrigation. Thus alternative cropping pattern would facilitate promoting drip irrigation in a larger scale.

V. CONCLUSION AND POLICY SUGGESTIONS

The study has revealed that adoption of drip irrigation technology has increased the net sown area, net irrigated area and thereby has helped in achieving higher cropping intensity and irrigation intensity. It has been found that there is a significant shift towards crops such as coconut and banana from crops like vegetables, paddy, sugarcane and the like. The main reasons have been found as scarcity of human labour and water. As the cropping pattern dictates the adoption and suitability of drip irrigation, widespread adoption of micro irrigation could be promoted in the regions where shift towards crops like coconut, banana are common. The analysis of economics of crop cultivation under drip and control has revealed that the drip method of irrigation has a significant impact on resources saving, cost of cultivation, yield of crops and farm profitability. The physical water and energy productivity is significantly high in drip over the flood method of irrigation. The adoption of drip irrigation is significantly influenced by experience, farm size, proportion of wider spaced crops and participation in non-farm income activities. Thus, our policy focus may be focused towards the promotion of drip irrigation in those regions where scarcity of water and labour is pronounced and where shift towards wider- spaced crops is taking place.

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