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Economic Benefits from Micro Irrigation for Dry Land Crops in Karnataka

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ABSTRACT

In this study the economic benefits from micro irrigation in the Eastern Dry Zone of Karnataka are estimated using primary data collected from a sample of 45 drip irrigation farmers (DIF) and 45 conventional irrigation farmers (CIF) drawing groundwater from irrigation wells. The size of holding in DIF (CIF) was 3.48 acres (2.77 acres). The major crops on DIF (CIF) were mulberry and grape (mulberry and tomato). Investment per functioning well in DIF (CIF) was ₹1,66,223 (₹1,31,551) because DIF had higher rate of well failure. The well failure rate for DIF (CIF) was 33 per cent (19 per cent). The annual negative externality cost was higher on DIF (₹8404) compared to CIF (₹4590). Groundwater extracted per farm in DIF (CIF) was 60 acre inches (94 acre inches). The net returns per acre inch of groundwater, net returns per rupee of water cost on DIF (CIF) were ₹457, ₹2.80 (₹194, ₹1.20). Using the intercept and slope dummy in the net returns function, it was found that by adopting drip irrigation the net returns per farm increased from ₹15,292 to ₹25,203 and the marginal productivity of water increased from ₹465 to ₹1960. Using discriminant function, to find the explanatory variables that differentiate the DIF and CIF, it was found that variables such as cropping intensity, water used (acre inches) and net returns per acre inch of water were the discriminant variables. Hence the government policy needs to be oriented towards these variables to motivate farmers to adopt drip irrigation. In addition, it is essential to promote irrigation literacy to enable farmers to use water efficiently.

Keywords: Micro irrigation, drip irrigation, evapo transpiration, crop productivity.

JEL classification: Q11, Q15, Q56

INTRODUCTION

The first experimental system of drip irrigation was established in 1959 by Netafim, an irrigation company by Blass in partnership with Kibbutz Hatzerim in Israel. They developed and patented the first practical surface drip irrigation emitter. In the United States, the first drip tape, called *Dew Hose*, was developed by Richard Chapin in 1960. In India, the Jain irrigation company heralded drip (micro) irrigation in 1989 developing `Integrated System Approach'.

With 10.80 million hectares of cropped area in Karnataka state, 21.50 per cent is irrigated and the rest 78.5 per cent is rainfed. Two-thirds of the geographical area is in the semi-arid zone receiving less than 750 millimeters of rainfall suffering frequent droughts. The progressive farmers in dry land, began using drip system in the late 1970s without any support from the State. Later, due to policy support, use of drip irrigation system (DIS) has spread primarily to irrigate high value dry land

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horticultural crops. Maharashtra has witnessed steep rise in DIS in 1988. Currently, the total area under drip irrigation is 0.62 mha in India and 0.114 mha in Karnataka.

CURRENT STATUS

Karnataka ranks third in the installation of drip irrigation in India. In recognition of the increasing probability of well failure to the tune of 0.4 in Karnataka, the State provided subsidy of 50 to 100 per cent for drip installation through the Departments of Horticulture and Agriculture. The subsidy amount accounted for ₹95.53 million covering an area of 8284 hectares. Among horticultural crops, coconut ranks first (27784 ha) in area, followed by arecanut (11139 ha), mango (6286 ha), grapes (3983 ha), sapota (1139 ha) and flowers and vegetables in the area covered by drip irrigation in Karnataka. Under the National Horticultural Mission, farmers in 25 out of the 27 districts in Karnataka get a 75 per cent subsidy for installing drip irrigation equipments, while those in Bijapur and Kolar districts get 100 per cent subsidy.

Karnataka, the second dry region in the country after Rajasthan, is a pioneer in implementing drip and sprinkler irrigation to save water, power and labour and also help farmers to cope with the economic scarcity of groundwater. Of the 16.30 lakh hectares of land, only 1.64 lakh hectares have been drip irrigated.

Review of Studies

Chandrakanth and Romm (1990) in their study on institutional factors responsible for the decline of tank irrigation systems and growth of well irrigation in Karnataka observed that the water table in various parts of Karnataka declined from 25 feet to 160 feet below the surface. As a result, large number of dug wells were converted to dug-cum-borewells and the net area irrigated per well declined from 5 acres to 3.5 acres. The shift from dug well-labour intensive technology to dug-cum-borewell-capital intensive technology involved comparatively a higher investment requirement.

Nagaraj *et al*. (1994) using the Negative Binominal Distribution to find out the probability of well failure worked out that the total investment required for obtaining a successful well is equal to the [cost of successful well + (the probability of failed well X the number of wells to be drilled to obtain a successful well X the cost of failed well)]. Thus, in 2013 prices, the estimated total investment of a successful well in the eastern dry zone of Karnataka = ₹1,91,000 as the cost of successful well (of which ₹92,800 are drilling charges for 900 feet + ₹25,200 (as casing charges for 90 feet @ ₹280 per feet) + ₹44,000 (cost of delivery pipes @ ₹110 per foot for 400 feet) + ₹29,000 (for a 12.5 HP pump and motor with 15 stages) + 0.4 (probability of failed well) X 1.67 (wells to be drilled to obtain a successful well) X ₹ (92,800) (cost of failed well = drilling charges) = 2,52,990 for an average depth of 900 feet in the groundwater over-exploited hard rock areas of eastern dry agroclimatic zone of Karnataka.

Chandrakanth and Arun (1997) estimated the negative externality due to well interference in Kolar and Bangalore districts of Karnataka. Due to failure of irrigation well, the probability of drilling additional well was as high as 0.87 due to high probability of well failure of 0.40. This exacerbated negative reciprocal externality as farmers are involved in both causing and bearing the brunt of groundwater overdraft. The willingness to pay for drilling additional well to mitigate externality was Rs.48,370 (in 1994 prices). The valuation of externalities is crucial in appreciating the positive role of subsidies and incentives which promote efficient groundwater use like drip or sprinkler irrigation system and the havoc played by subsidies like free electricity and soft loans for well irrigation which promote rapid exploitation of the precious groundwater resource. Considering the huge investment of ₹48,370 on an additional well, it may be worthwhile examining whether investment on structures like drip or sprinkler systems which aid in efficiently utilising the available groundwater is better than investment on a new well. Investment on a new well will not only increase the groundwater utilisation, but also is subject to a great risk of premature failure, as compared with investment on drip or sprinkler system, which may provide opportunities to efficiently utilise the available groundwater. Accordingly in areas where cumulative well interference is apparent, provision of incentives like free electricity supply and providing soft loans for well irrigation may exacerbate the negative externalities, while provision of incentives like subsidies on sprinkler and/or drip irrigation systems, high density poly ethylene pipes for lifting groundwater, capacitors in irrigation pumpsets, generate positive externalities, by way of reducing groundwater exploitation and cumulative well interference.

Shashidhara *et al.* (2007) conducted the study on drip irrigation in arecanut and banana in Shimoga and Davanagere districts of Karnataka. A majority of the drip irrigation farmers expressed saving of water (95 per cent), saving in labour cost of irrigation (92 per cent) and uniform application of water (91 per cent). Improved quality of the produce was expressed by 70 per cent of the farmers. Drip irrigation increased returns by 5.92 per cent and 3.54 per cent in coconut and arecanut with a B: C ratio (1:3.36) as compared to surface irrigation (1:2.81). Quality parameters of banana (Yelakki bale) crop grown under drip system had shown more number of hands per bunch (12), fingers per bunch (103), length of fruit (4.73 inches) and fruit thickness (2.53 inches). The drip irrigation had minimised the days for harvesting (to 398 days) and also increased shelf-life (of 15 days) in banana.

METHODOLOGY

In Karnataka, drip irrigation is common in eastern dry agroclimatic zone of Karnataka due to acute economic scarcity of groundwater. Here grapes, mulberry, tomatoes and other vegetables are popularly cultivated. A sample of 90 farmers consisting of 45 farmers using groundwater with drip irrigation (DIF) and another 45 farmers using groundwater with conventional irrigation (CIF) growing grapes, mulberry, tomatoes on their farms in Chickballapur district were chosen for this study (Priyanka, 2009). Primary data for the study was obtained from personal interviews during December 2008-January 2009, using structured pre-tested schedule. The information elicited included *inter alia* (1) socio-economic features of respondents, (2) cropping pattern, (3) land holdings, (4) sources of irrigation, (5) investment on irrigation wells, (6) costs and returns from crops grown under well irrigation and (7) volume of water used measured in acre inches (one acre inch = 22611 gallons of water = 1 ha cm).

The economic efficiency of water use was analysed in terms of net income per acre-inch of water and technical efficiency in terms of output per acre-inch of water used. Regression analysis was used to know the factors influencing the net returns per farm. Tobit model was used to estimate the farmer's willingness to invest in drip irrigation system and discriminant analysis was used to find out the variables that differentiate drip irrigation farmers from conventional irrigation farmers.

Cropping Pattern

Considering gross cropped area, in drip farms the area under mulberry (sericulture) formed around 40 per cent, area under grapes formed around 48 per cent, ragi formed 4.35 per cent of the gross cropped area (GCA) in *kharif,* and 3.72 per cent of GCA *rabi*. In conventional farms, the area under mulberry formed 33 per cent, grapes formed 8 per cent, ragi formed 18 per cent in *kharif* and 9 per cent in *rabi* and formed 5 per cent of GCA in summer. The cropping intensity was comparable in both the situations (Table 1). The area under perennial crops enabled farmers to adopt drip irrigation as compared with annual crops dominating in conventional irrigation farms. However whether drip irrigation was introduced first, or the perennial crops were introduced first, is a hen-egg question. In order to cope with water shortage for the already planted perennial crops, drip irrigation was introduced.

Well Failure

In drip irrigation farms, 36 per cent belonged to marginal farms with the average size of holding of 1.39 acres, 51 per cent of farms belonged to small farms with an average holding size of 3.55 acres and 13 per cent belonged to large farms with holding size of 8.75 acres. Considering all the farms, 33 per cent of wells had failed, and 67 per cent of wells were functional at the time of data collection (2008). The earliest well drilled in 1958 and the latest during 2007. In conventional irrigation sample farms, 38 per cent farms belong to marginal farms with average size of holding of 1.17 acres, 60 per cent of farms belong to small farms with average holding size of 3.32 acres and 2 per cent belong to large farms with holding size of 6 acres. Considering all the farms, 19 per cent of wells had failed wells and 81 per cent

TABLE 1. CROPPING PATTERN IN DRIP AND CONVENTIONAL IRRIGATION FARMS IN EASTREN DRY ZONE OF KARNATAKA

(*acres*)

	Drip irrigation farms (n=45)		Conventional irrigation farms (n=45)	
Crops (1)	Area (acres) (2)	Proportion of GCA (3)	Area (acres) (4)	Proportion of GCA (5)
		Kharif		
Ragi	12.00	4.35	44.00	18.24
Jowar	3.00	1.09	7.00	2.90
Horse gram	-	-	3.50	1.45
Beans	-	-	1.50	0.62
Tomato	3.00	1.09	14.00	5.80
Potato	-	-	5.50	2.28
Chilli	-	-	2.00	0.83
Sub-total	18.00	6.53	77.50	32.12
		*Ra*bi		
Ragi	10.25	3.72	23.00	9.53
Jowar	-	-	2.00	0.83
Tomato	-	-	5.00	2.07
Potato	-	-	2.00	0.83
Chilli	-	-	4.00	1.66
Sub-total	10.25	3.72	36.00	14.92
		Summer		
Ragi	3.50	1.27	11.25	4.66
Tomato	1.00	0.36	17.00	7.05
Sub-total	4.50	1.63	28.25	11.71
		Perennials		
Grapes	133.50	48.41	20.00	8.29
Mulberry	109.50	39.71	79.50	32.95
Sub-total	243.00	88.12	99.50	41.24
Gross cropped area	275.75	100	241.25	100.00
Net cropped area	139.50		127.25	
Cropping intensity	197.67		189.58	

Notes: Gross cropped area (GCA) under grapes is considered as twice their net area and mulberry is considered as two times of net area giving weightage to the perennial crops; GCA- Gross cropped area; NCA- Net cropped area.

of wells were functional at the time of data collection (2008). The earliest well was constructed in 1958 and the latest was drilled during 2008 (Table 2).

Profile of Irrigation Wells

In DIF, 64 (67 per cent) bore wells were functioning, whereas in CIF 46 (81 per cent) bore wells were functioning. Even though the number of wells possessed by farms in DIF was higher as compared to CIF, the proportion of functioning wells was lower in DIF (67 per cent) as compared to CIF (81 per cent) and the proportion of well failure was the highest in DIF (33 per cent) as compared to CIF (19 per cent).

Considering the investment on irrigation bore wells in the two situations, investment per well in DIF (₹1,11,982) was comparable to CIF (₹1,10,165). Investment per functioning well was 26 per cent higher for farms with drip irrigation (₹1,66,223) as compared to conventional irrigation farms (₹1,31,551) because of high well failure.

TABLE 2. DISTRIBUTION OF IRRIGATION WELLS ACROSS SIZE OF HOLDING IN EDZ OF KARNATAKA

Type of farms (1)	Size of holding (acres) (2)	No. of farms (per cent) (3)	Functioning/ working wells (per cent) (4)	Non-functioning/ failed wells (per cent) (5)	Total no. of wells (6)	Range of years of drilling (7)
			Drip irrigation farms			
Marginal farms (< 2.5 acres)	1.39	16 (35.56)	16 (61.53)	10 (38.46)	26	1970-2006
Small farms (2.5 - 5 acres)	3.55	23 (51.11)	35 (71.43)	14 (28.57)	49	1958-2007
Large farms (> 5 acres)	8.75	6 (13.33)	13 (65.00)	7 (35.00)	20	1976-2006
All farms	3.48	45	64 (67.37)	31 (32.63)	95	1958-2007
			Conventional irrigation farms			
Marginal farms (< 2.5 acres)	1.17	17 (37.78)	17 (80.95)	4 (19.05)	21	1958-2006
Small farms (2.5 - 5 acres)	3.32	27 (60.00)	28 (80.00)	7 (20.00)	35	1977-2008
Large farms (> 5 acres)	6	1 (2.22)	1 (100)	0 (0.00)	1	2004
All farms	2.77	45	46 (80.70)	11 (19.30)	57	1958-2008

Note: EDZ: Eastern dry agrcolimatic zone. Figures in parentheses indicate percentage to the respective total.

The amortised cost per well was lower (₹17,350) for drip irrigation farms than conventional irrigation farms (₹19,196) due to higher number of wells in DIF (95) than CIF (57). The amortised cost per functioning well was higher (₹25,754) for drip farms than CIF (₹23,786). The DIF had higher proportion of well failure (33 per cent) compared to conventional irrigation farms (19 per cent). Hence even though the modal age of wells in both the situations are the same, as the well failure and the investment per well was higher due to drip irrigation on DIF, the annual negative externality cost is 85 percent higher on DIF compared to CIF (Table 3). Thus, if the amortised cost per well (considering all the wells) is the same as the amortised cost of functioning wells, then there are only functional wells and no failures. If the failure rate is large, then the gap between the amortised cost per well and that the per functioning well would also be large and hence the cost of well failure can be considered as externality cost.

Net Returns in Drip Irrigated Farms and Conventional Irrigated Farms

The drip farms realised higher net returns from tomato (₹26,208) than in farms with conventional irrigation (₹22796). Similarly, in mulberry cultivation, drip farms realised higher net returns per acre per crop (₹7621) compared to conventional irrigation farms (₹4978). Considering the net returns per acre per crop from grapes, drip farms realized higher returns (₹52,084) than that of conventional irrigation farms

(₹21,489). The net return per acre inch of groundwater used realised was higher for drip farms from tomato, mulberry and grapes (₹2696, ₹1,384 and ₹4,723 respectively) than that for farms with conventional irrigation (₹1040, ₹525 and ₹769 respectively) (Table 4).

TABLE 3. PROFILE OF IRRIGATION WELLS ON DRIP AND CONVENTIONAL IRRIGATION FARMS

Sl. No. (1)	Particulars (2)	Drip irrigation farms (3)	Conventional irrigation farms (4)	Per cent change (Drip over conventional) (5)
1.	Sample farms (No.)	45	45	-
2.	Functioning bore wells (No.)	64 (67)	46 (81)	39
3.	Non-functioning Bore wells (No.)	31 (33)	11 (19)	182
4.	Total bore wells (No.)	95	57	67
5.	Average age of functioning wells (years)	9.83	9.28	6
6.	Average life of premature failed wells (years)	9.13	7.09	29
7.	Average age of all wells (years)	9.58	8.93	7
8.	Modal age of wells (years)	9	9	-
9.	Depth of Bore wells (feet)	536	570	-6
10.	Yield of well (gallons per hour- GPH)	1663	1739	-4
11.	Range of wells drilled (years)	1958-2007	1958-2008	-
12.	Earliest year of drip irrigation system installed	2000	N.A.	
13.	Modal year of drip irrigation	2004	N.A.	-
14.	Investment per well (₹) in 2008	111982	110165	2
15.	Investment per functioning well (₹) in 2008	166223	131551	26
16.	Amortised cost per well (₹) in 2008	17350	19196	-10
17.	Amortised cost per functioning well (₹)	25754	23786	8
18.	Annual negative externality cost (₹) (17-16)	8404	4590	85

Note: NA- Not applicable, Figures in parentheses are percentage to the respective total.

TABLE 4. NET RETURNS OF CROPS UNDER DRIP AND CONVENTIONAL IRRIGATION

Per crop of (1)		Potato (2)	Chilli (3)	Tomato (4)	Mulberry* (5)	Grapes (6)
Cost of cultivation per acre (Rs.)	DI	NC	NC	19542	15165	22961
	CI	24471	10520	20793	16939	25686
Gross return per acre (Rs.)	DI	NC	NC	45750	22786	75045
	CI	36267	18593	43589	21917	47175
Net return per acre (Rs.)	DI	NC	NC	26208	7621	52084
	CI	11796	8073	22796	4978	21489
Water use per acre (acre inch)	DI	NC	NC	9.72	5.51	11.03
	CI	22.44	15.24	21.90	9.48	27.94
Net return per acre-inch of water (Rs.)	DI	NC	NC	2696	1384	4723
	CI	526	530	1040	525	769
Net return per rupee of water (Rs)	DI	NC	NC	2.47	2.88	12.84
	CI	1.55	1.95	2.21	1.24	10.26
Net return per kg of output (Rs.)	DI	NC	NC	2.17	1.53	4.50
	CI	1.50	1.47	2.07	1.35	2.69
Output per acre-inch of water (kg)	DI	NC	NC	1245	905	1050
	CI	349	360	503	386	285
Cost per kg of output (Rs.)	DI	NC	NC	1.61	3.04	1.98
	CI	3.13	3.39	1.88	4.63	3.22
Output per acre (kg)	DI	NC	NC	12100	4981	11577
	CI	7826	5483	11015	3662	7975

NC- Not cultivated, CI =conventional irrigation farms, DI= drip irrigation farms;
*For mulberry farms, output and returns reflect those from the mulberry leaves excluding cocoons.

The net return per rupee of water from tomato, mulberry and grapes realised by drip farms was higher (₹2.47, ₹2.88 and ₹12.84 respectively) than that by conventional irrigation farms (₹2.21, ₹1.24 and ₹10.26 respectively). Considering the output per acre-inch of groundwater from tomato, mulberry and grapes, drip farms produced higher (1245 kg, 905 kg and 1050 kg respectively) than that in conventional irrigation farms per crop (503 kg, 386 kg and 285 kg respectively) (Table 4).

The net return per acre per crop from mulberry and grapes was higher in drip farm (₹7681 and ₹52084) than that for conventional irrigation farms (₹4978 and ₹21489) respectively. Similarly, the net return per acre inch of groundwater used realised was higher in drip farms from tomato cultivation (₹26208) than that in conventional irrigation farms (₹22796).

Technical Efficiency

The technical efficiency of water use is defined in terms of output per acre inch of water and water used per quintal of output. In drip irrigation system, 9.05 qtls of mulberry leaves, 10.50 qtls of grapes and 12.45 qtls of tomato were produced per acre inch of water while in conventional irrigation systems 3.86 qtls of mulberry, 2.85 quintals of grapes and 5.03 quintals of tomato were produced per inch of water. The volume of water used to produce one quintal of mulberry, grapes and tomato was the lowest in DIF (0.11 acre-inch, 0.09 acre-inch and 0.08 acre-inch, respectively) than CIF (0.26 acre-inch, 0.35 acre-inch and 0.19 acre-inch respectively). Output per acre inch of water used in DIF is 234 per cent higher in mulberry, 368 per cent higher in grapes and 248 per cent higher in tomato as compared to CIF. In DIF 42, 26 and 42 per cent of water has been saved as compared to CIF in mulberry, grapes and tomato respectively (Table 5).

Economic Efficiency of Water Use

The economic efficiency of water use can be defined in terms of net return per acre inch of water, net return per acre, and net return per rupee of water used for irrigation. The net returns per acre-inch of water from mulberry, Grapes and tomato were the highest in DIF (₹1384, ₹4723 and ₹2696 respectively) than CIF (₹525, ₹769 and ₹1040 respectively). The net returns per acre of mulberry, grapes and Tomato in DIF was relatively higher (₹7621, ₹52,084 and ₹26,208 respectively) than CIF (₹4978, ₹21,489 and ₹22,796 respectively) (Table 5). Thus, the technical and economic efficiency indicates that the positive externality due to groundwater use in drip irrigation over conventional irrigation is higher than the negative externality due to groundwater use in drip irrigation (given by the annual negative externality cost due to well failure).

TABLE 5. WATER USE EFFICIENCY IN DRIP AND CONVENTIONAL IRRIGATION FARMS IN EASTERN DRY ZONE OF KARNATAKA

	Technical efficiency		Economic efficiency		
Particulars	Output per acre-inch of water (quintals)	Water used per quintal of output (acre-inch)	Net return per acre-inch of water (₹)	Net return per acre (₹)	Net return per rupee of water (₹)
(1)	(2)	(3)	(4)	(5)	(6)
Mulberry					
Drip irrigation farms (DI)	9.05	0.11	1,384	7,621	2.88
Conventional irrigation farms (CI)	3.86	0.26	525	4,978	1.24
Efficiency (per cent)	234	42	264	153	232
Grapes					
Drip irrigation farms	10.50	0.09	4,723	52,084	12.84
Conventional irrigation farms	2.85	0.35	769	21,489	10.26
Efficiency (per cent)	368	26	614	242	125
Tomato					
Drip irrigation farms	12.45	0.08	2696	26208	2.47
Conventional irrigation farms	5.03	0.19	1040	22,796	2.21
Efficiency (per cent)	248	42	259	115	112

Note: Efficiency= [DI/CI]*100.

Marginal Productivity of Groundwater in Drip and Conventional Irrigation Farms

Net return function per farm was estimated to capture the influence of (i) the volume of water used in drip and conventional irrigation, (ii) dummy variable assigning 0 for conventional farm and 1 for drip farm; and (iii) the interaction between the method of irrigation and volume of water used (interaction dummy). The dummy variable is used to differentiate the type of irrigation system assigning 1 for drip irrigation and 0 for conventional irrigation farms. The estimated model is $Y = \alpha + \beta_1 X + \beta_2 D + \beta_3 DX + U_i$, where Y = annual net returns obtained in ₹per farm, X = annual irrigation water applied to crops in acre inches per farm, D is the (0,1) intercept dummy variable representing the shift in the net returns on farms with drip irrigation, DX is the slope dummy variable measuring the rate of increase in net returns due to the interaction of the groundwater volume applied and the drip irrigation method. The resulting net return function with t values in parentheses is

$$Y = 15292 + 465X + 9911D + 1960\,DX \quad \text{....(1)}$$

t = (1.41) (2.45) (0.72) (6.17), Adj $R^2 = 0.56$, $R^2 = 0.76^{**}$, F = 36, n=81 farmers

From the regression (1), the threshold net return is ₹15292 per farm which is the contribution of inputs other than irrigation water. The marginal productivity of groundwater is ₹465 per acre inch at any level of use of water (as this is a linear function) obtained by differentiating the dependent variable with respect to groundwater. Due to drip irrigation, the threshold net return per farm is shifted by

₹9911 as given by the coefficient of the dummy variable used to differentiate the drip irrigation farms from conventional irrigation farms. Hence the threshold net return per farm due to drip irrigation = ₹15292 + ₹9911 = ₹25203 for drip irrigation farms. The marginal productivity of the drip method of irrigation = ₹1960 per farm of drip irrigation. The marginal productivity of the groundwater applied through drip irrigation then = ₹465 + ₹1960 = ₹2425 per acre inch. The total net return per farm due to use of groundwater through drip irrigation at the average level of use of groundwater = ₹15292 + 465 * 28.9 acre inches per farm + 9911 * (1) + 1960 * (1) * (28.9) = ₹95285.

Thus, the net return for drip irrigation farms is given by Y = (15292 + 9911) + (465+1960) * X inches per farm which yields the function (2) as under:

Y = 25203 + 2425 X for drip irrigation farmers …. (2)

Net Return Function for Conventional Irrigation Farms

The regression (3) is for farmers using conventional irrigation, whose threshold net return is ₹15292 per farm reflecting the contribution of all the factors of production other than irrigation water. The marginal productivity of groundwater is ₹465 per acre inch at any level of use of water. The total net return per farm due to use of groundwater through flow irrigation at the average level of use of groundwater = ₹15292 + 465 * 28.9 acre inches per farm = ₹28,730. For one acre inch increase in water use from the mean level, the net returns per farm increases by ₹465. The resulting net return for conventional irrigation farms is given by

Y = 15292 + 465X for conventional or flow irrigation farms ….(3)

Investment Behaviour of Drip Irrigation Farmers (Tobit)

The investment in drip irrigation made by farmers is regressed on independent variables such as net return per farm (₹) and water used in acre inches per farm. The investment on drip irrigation is the actual cost of drip irrigation in drip farms, while it is zero Rupees for farms with conventional irrigation. The willingness to pay for drip irrigation is thus estimated using the Tobit maximum likelihood model where, at least one value for dependent variable should be zero (Table 6). The results (of the SAS output) indicated that the variables, net return per farm (₹) and water used in acre inches were significant at 5 and 1 per cent respectively. The log likelihood function was significant with a high value of - 401. For every acre inch of water saved in drip irrigation, the willingness to invest on drip irrigation increases by ₹932.[1] The minimum investment for drip irrigation is ₹10,262 per farm. The average drip investment per farm was ₹41,115 and per acre was ₹15,450. For every one rupee increase in net returns per farm, the willingness to pay for drip irrigation increases by

0.23 rupee. The results amply demonstrate the scarcity value of groundwater as reflected in motivating farmers to invest ₹933 on drip irrigation for every one acre inch of groundwater saved in the process of adoption of drip irrigation.

TABLE 6. INVESTMENT BEHAVIOR BY DRIP IRRIGATION FARMS (TOBIT MODEL)
DEPENDENT VARIABLE: INVESTMENT IN ` PER FARM ON DRIP IRRIGATION FARMS

Variable (1)	Coefficient (2)	Standard Error (3)	t-value (4)
Intercept	10262**	5.12	1967
Net return per farm (₹)	0.23*	0.10	2.22
Water use (acre inches) per farm	-932.96**	247	-3.77
Number of observations			68
Log likelihood function			-401

Note: * and * * indicates significance level at 5 and 1per cent respectively.

The negative coefficient for water use per farm (being ₹ -933) is, if there is savings in water use (due to drip irrigation), the investment in drip irrigation farms will increase by ₹933.

Results of the Discriminant Function Analysis

In order to identify the key variables that discriminate between the DIF and CIF, stepwise discriminant function analysis is run. The Structure matrix indicated that out of the 6 variables considered in the analysis, the variables such as Cropping intensity (X_1), water used in acre inches (X_2) and net returns per acre inch of water (X_3) were found to be important based on their power to discriminate between DIF and CIF and hence are the significant discriminators between farmers who adopt drip irrigation and conventional irrigation. The estimated function is $Z = 0.80X_1+0.28X_2+0.14X_3$. The calculated value of Mahalanobis D^2 is 646.79. In order to find the relative importance of each of the variables in their power to discriminate between the two groups; the percentage contribution of each variable to the total distance measured is worked out (Table 7). Thus, the major variable among the three discriminating

TABLE 7. FACTORS DISCRIMINATING DRIP AND CONVENTIONAL IRRIGATION FARMS IN EASTERN DRY ZONE OF KARNATAKA

			Group mean value			
Sl. No. (1)	Discriminating variable (2)	Discriminating co-efficient (L_i) (3)	DIF members (d_1) (4)	CIF members (control) (d_2) (5)	$L_i(d_1-d_2)$ (6)	Contribution (per cent) (7)
1.	Cropping intensity	0.803	268	265	2.409	0.37
2.	Water used in acre inch	0.283	23	43	5.666	0.88
3.	Net returns per acre inch of water	0.142	5462	964	638.716	98.75

$D^2 = 646.79$.

variables is the net returns per acre inch of water which accounts for 98.75 per cent of the total distance between the groups. Thus, the farmers shift to drip irrigation, largely considering the net returns they can realise per acre inch of groundwater. This is an apparent indicator of the farmers' response to the rising cost of groundwater resource due to negative externalities fraught with groundwater irrigation in the hard rock areas in the eastern dry zone of Karnataka.

CONCLUSIONS

There are no compelling reasons to disbelieve that recurrence of drought or excessive rainfall are a phenomena due to climate change. The manifestation of drought on groundwater wells is both direct and indirect; the direct effect is on crop productivity and increased evapo-transpiration. The indirect effects are on the volume of groundwater extracted, declining yield of groundwater from wells over time till such wells get recharged. It is possible that if there is no recharge such wells may be completely dried up. If the farmers in contiguous blocks such as Yelluvali, Doddamaralli have adopted drip irrigation enmasse, this is a *prima-facie* indicator of the farmers' response to rising costs of groundwater due to negative externalities from cumulative interference of irrigation wells and to cope with drought (especially since 2001). Even though subsidy for drip irrigation as a governmental programme was extended, since 1980, farmers selectively began adopting drip irrigation depending upon the crop cultivated. The drip irrigation was first adapted to perennial broad espacement crops such as grapes. Later drip irrigation was adapted to mulberry. In the years after 2000, farmers in eastern dry zone began adapting drip irrigation to seasonal commercial crops such as tomato, floriculture. There are no compelling reasons to believe that large scale adoption of DI is due to subsidy, as subsidy programme began much earlier. The adaption of drip irrigation is largely due to the effect of economic scarcity of groundwater due to cumulative interference of irrigation wells resulting in high probabilities of initial and premature well failure.

This study has apparently shown that the farmers of eastern dry agroclimatic zone (especially from Kolar and Chikkaballapura) have demonstrated to the world that drip irrigation is adapted to cultivate even narrow spaced crops due to the rising cost of groundwater due to negative externalities resulting from cumulative interference among irrigation wells. The farmers thus resorted to drip irrigation due to enhanced marginal productivity of water, savings in water use and the net returns per unit volume of groundwater. Despite these benefits and the policy support through subsidy for drip irrigation system, the diffusion of drip irrigation technology for narrow spaced crops in other parts of India is not appreciable. Hence, it is necessary for the Departments of Agriculture and Horticulture in different states to chalk out an intensive outreach programme for expanding the drip irrigation for narrow and broad spaced crops. In addition, the Governments need to have a close watch on the quality of drip irrigation equipments used by different vendors to save the farmers from the poor quality equipments including conveyance tubes and drippers. This calls for developing a cadre of agricultural engineering diploma holders who can be a good human resource to be used by the developmental departments for the benefit of farmers striving hard to realise the economic value of groundwater.

NOTE

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REFERENCES

Chandrakanth, M.G. and V. Arun (1997), "Externalities in Groundwater Irrigation in Hard Rock Areas", *Indian Journal of Agricultural Economics*, Vol. 52, No.4, October-December, pp. 761-771.

Chandrakanth, M.G. and Jeff Romm (1990), "Groundwater Depletion in India – Institutional Management Regimes", *Natural Resources Journal*, Vol.30, pp. 485-502.

Nagaraj, N.; M.G. Chandrakanth and Gurumurthy (1994), "Borewell Failure in Drought-Prone Areas of Southern India: A Case Study", *Indian Journal of Agricultural Economics*, Vol. 49, No. 1, January-March, pp.101-106.

Priyanka, C.N. (2009), *Externalities in Groundwater Use on Drip and Conventional Irrigation Farms in the Eastern Dry Zone of Karnataka*, Submitted to the Department of Agricultural Economics, University of Agricultural Sciences, Bangalore, MSc (Agri) Thesis, Unpublished.

Shashidhara, K.K.; A. Bheemappa, L.V. Hirevenkanagoudar and K.C. Shashidhar (2007), "Benefits and Constraints in Adoption of Drip Irrigation Among the Plantation Crop Growers", *Karnataka Journal of Agricultural Sciences,* Vol.20, No.1, pp. 82-84.