from flow irrigation are constrained to adopt drip irrigation for all the crops on their farms.

Thus, the highest economic efficiency has been for farmers using drip irrigation. Farmers adopting drip irrigation have proved their economic worthiness by adjusting with the limited groundwater yield, when compared with farmers who have risked by drilling additional well/or by deepening the existing irrigation well, to augment water supplies.

Groundwater resource is becoming increasingly scarcer over time and space in the dry agro-climatic zones of Karnataka. This is apparent *inter alia* due to increased proportion of well failure, drastically reducing age and life of irrigation wells, virtual shift from dug wells to bore-wells for groundwater irrigation. Given the modest interest on the part of the farmers as well as the policy makers on augmenting the supply side of groundwater through watershed development and tank desiltation programmes including the institutional innovations, farmers are resorting to bringing efficiency in water use through drip irrigation or by supply side approach by drilling additional well/or by reboring existing well/s. The economic message is that under the situations of economic scarcity of groundwater, it would be wise on the part of the farmers to resort to water-use efficiency rather than venturing on additional source/s of groundwater, which is/are not only risky to strike but also risky to sustain.

For outreach, the major variable identified by the studies is the 'net return per acre-inch of groundwater' used, as this has accounted for 99 per cent of the total Mahalanobis distance between farmers adopting drip irrigation and farmers using conventional method of irrigation. The farmers need to be educated regarding this crucial variable along with technical aspects of drip irrigation.

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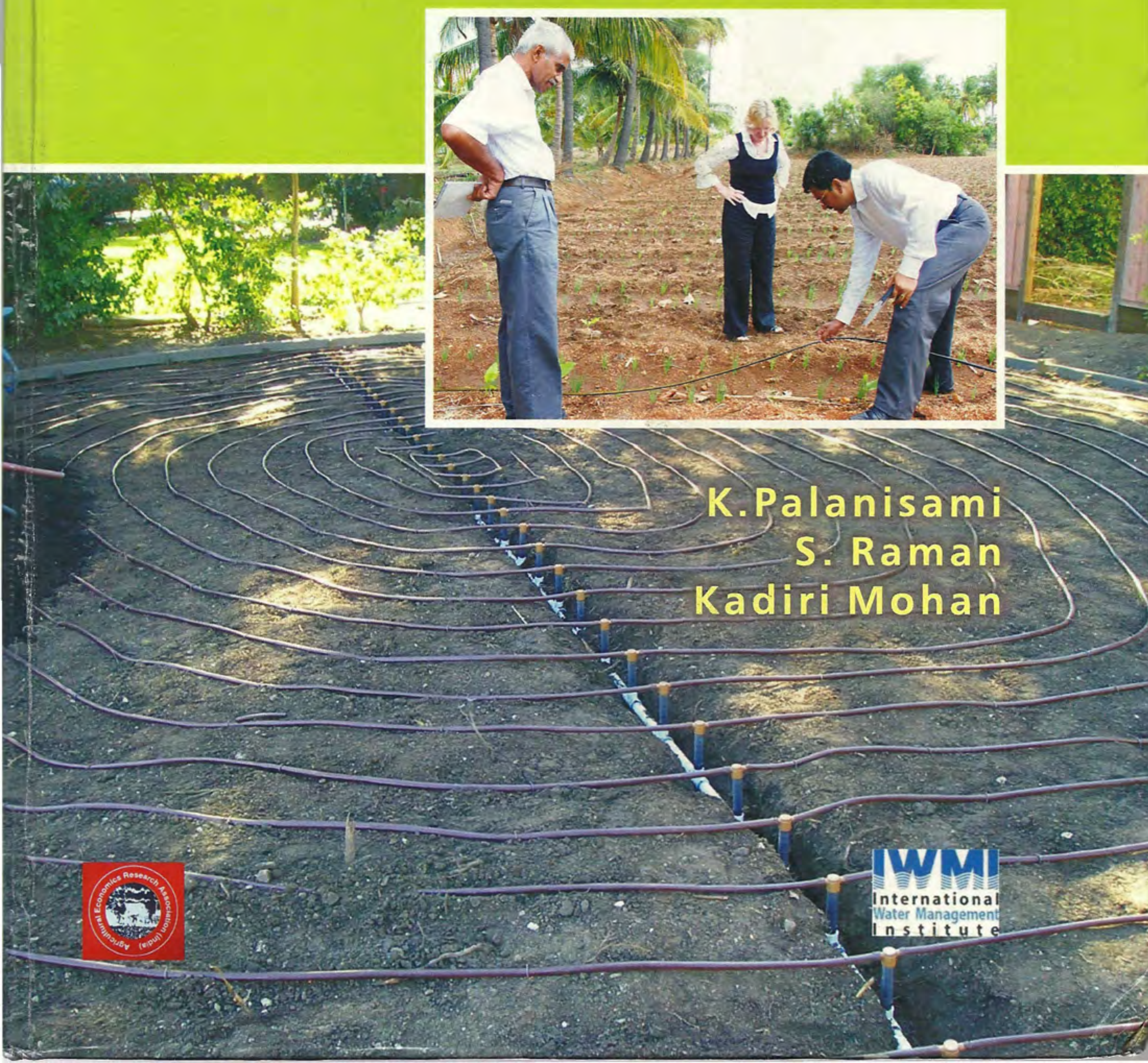

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Contents

CHAPTER 3

Micro-Irrigation: Economics and Outreach in Karnataka

M.G. Chandrakanth, G.L. Thamanadevi, N. Nagaraj, C.N. Priyanka, M. Mamatha, P.S. Srikanthamurthy, M. Prakashkumar, Y. Nagaraju, G. Sanjeev, Ravi Hosur, Umesh Pradhani, Basavaraj Biradar and Ranganath Mangalvedkar

INTRODUCTION

In India, both surface and groundwater are dependent on the monsoons. More than 85 per cent of groundwater is used for irrigation. Thus, rainfed, surface water irrigated and groundwater irrigated agriculture suffers from the vagaries of monsoon. The quantum and distribution of rainfall is a major determinant of the farm economy, irrespective of whether the farm is rainfed or irrigated. Irrigation efficiency in general and economic efficiency in the use of irrigation water in particular, shapes the economy of the farming sector. In surface water irrigation, dominated by reservoirs and canal systems, the entire investment is borne by the public, while farmer does not bear any cost of infrastructure. The farmer using surface water is required to remit just the water charges as water rate. In several states, farmers do not remit the water rate/water charges for surface water, virtually treating surface water as a 'free' public good. In the case of groundwater, however, the farmer necessarily contributes for groundwater well, pump set, electrical fixtures, conveyance pipes and other accessories, including drip/sprinkler irrigation, if any. In addition, he/she is required to pay for the electricity used to pump groundwater for irrigation. Farmers, in most of the states in India do not pay for electricity used to pump groundwater. Thus, the irrigation sector is fraught with low revenue-high investment muddle and the associated negative externalities.

IMPORTANCE OF WATER IN AGRICULTURE

Water is a lifeline for all activities and it serves as a productive and protective input in agriculture. For the success of green revolution, irrigation has contributed significantly. It is estimated that irrigation contributes around 60 per cent to the growth of agricultural productivity. In India, about one-third of the cultivated area is under irrigation, whereas groundwater and surface water have equal shares in gross irrigation. The importance of irrigation is viewed in terms of achieving food security, stability in agricultural output and yield, and resilience in agricultural production system.

Drip irrigation as a coping mechanism is used mainly for widely-spaced crops. However, at present, due to availability of technology, it is being used even for close-spaced crops like vegetables. This certainly is a welcome development as farmers cultivating diverse crops will appreciate and follow water-use efficiency in letter and spirit. In India, the area covered under drip irrigation is meager. Considering the proportion of the total area under drip irrigation across different states, around 46 per cent of the total area under drip irrigation in India is in Maharashtra, followed by Andhra Pradesh (16.35%), Karnataka (16.11%), Tamil Nadu (7.56%), Gujarat (5.02%) and other states (8.5%). While considering crops under drip irrigation, orchard crops dominate with 46.11 per cent of the total area under drip irrigation followed by plantation crops (16.65%), coconut and arecanut (4.13%), vegetables (2.17%) and others (30.94%).

In order to meet the irrigation requirements, farmers are adopting various coping mechanisms like deepening of the existing wells, drilling additional wells and resorting to drip irrigation system. Thus, farmers are incurring additional costs in the extraction and use of groundwater for irrigation in these areas.

IRRIGATION IN KARNATAKA

In Karnataka, 1695 TMC (thousand million cubic feet) of surface water forming 78 per cent of the total volume of water irrigates 50 per cent of the irrigated area of 16,85,548 ha, while the remaining 485 TMC of groundwater forming 22 per cent of the total volume of water, irrigates the rest of the 50 per cent of the irrigated area. This shows the lopsided distribution of surface water compared to groundwater resources in the state. Thus, *prima facie,* there are compelling reasons to bring efficiency of water-use in both surface irrigation and groundwater irrigation. Relatively, groundwater farmers are more efficient than the surface water farmers, as 485 TMC of groundwater forming 22 per cent of water is spread on 50 per cent of the irrigated land. And 1695 TMC of surface water, forming 78 per cent of water, is spread on other 50 per cent of irrigated land. Thus, 25 per cent of the total water (= groundwater) is used on half the irrigated land and 75 per cent of the total water (= surface water) is used on the other half of irrigated land in Karnataka.

The state of Karnataka depends on groundwater for irrigation to the extent of 51 per cent. Thus, the state depends almost equally on groundwater and surface water for irrigation (Table 3.1). Drip irrigation is feasible for groundwater irrigation and thus, the state has a vast scope to promote drip irrigation since 51 per cent of the irrigated area is under groundwater irrigation.

Table 3.1: Groundwater Structures and Irrigated Area in Karnataka, 2007

Groundwater Structures	*Number*	*Total Gross Irrigated Area (ha)*
Dug wells (or Open wells)	456463	483074
Tube-wells	619099	1288639
All wells	1075562	1771713
Total surface water and groundwater irrigated area		3457231

Source: Annual Season and Crop Statistics Report, 2007-08, Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

Need for Expanding Drip Irrigation in Karnataka

The drip and sprinkler systems were first developed in the groundwater-scarce Israel during the 1960s. This technology is spreading to different water-scarce regions of the world, including western and southern India and north China. In India, drip irrigation was introduced in the 1970s. Drip irrigation has been a success for citrus, orange and grapes in Maharashtra, for coconuts in Tamil Nadu, and mulberry, coconut, grapes and arecanut in Karnataka.

Techno-economically, drip irrigation perfectly fits into groundwater rather than surface water in India. Thus, area under drip irrigation has to expand in areas with groundwater irrigation. The proportion of area irrigated by groundwater, type of crops (annuals or perennials), probability of well failure, availability of funds and education of farmers largely influence the extent to which drip irrigation is adopted. The proportion of area irrigated by groundwater for different crops of Karnataka (2006-07). Table 3.2 indicates that among the popular field crops which are water-

Table 3.2: Crop-wise Area Irrigated by Canals, Irrigation Tanks, Wells and Other Sources for Important Crops of Karnataka, 2006-07

Crop	*Area Irrigated by Canals (ha)*	*Area Irrigated by Irrigation Tanks (ha)*	*Area Irrigated by Wells (ha)*	*Area Irrigated by Other Sources (ha)*	*Gross Irrigated Area byAll Sources ('000 ha)*	*Percentage of Area Irrigated by Wells Out of the Gross Irrigated Area*
Paddy	631456	119452	184808	97186	1033	18
Jowar	0	0	68261	24307	149	46
Ragi	7832	4837	25516	354	39	66
Bajra	17819	242	25 807	5653	50	52
Maize	122246	9159	233991	81646	447	52
Wheat	56744	1668	61196	23292	143	43
Red gram	19407	77	9032	662	29	31
Sugar cane	94781	9268	262108	112906	479	55
Groundnut	56237	1829	123816	24938	207	60
Cotton	32134	39	20114	3633	56	36

Source: Annual Season and Crop Statistics Report, 2007-08, Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

intensive, sugarcane is the single largest crop which uses 55 per cent of the total irrigated area, followed by maize (52%) and cotton (36%). For other field crops, adoption of drip irrigation is a question as technologies are yet to develop.

WATER RESOURCES OF THE STATE

Karnataka has an estimated flow of 1,695 thousand million cubicfeet (TMC) of surface water and 485 TMC of groundwater every year. The estimated demand and supply is subject to the limitation of methodology used and the source of data used. The positive gap (Table 3.3) is due to the lack of infrastructure to store the rain/river water. Groundwater utilization, according to volume exceeds 70 per cent of supply or availability. The demand for irrigation is estimated using the crop water requirement. Around 29 per cent of the cropped area of Karnataka is irrigated. The demand for industrial use is of 16.62 TMC in Krishna Basin and twice of this is taken for the state. The demand for livestock is similarly estimated using the 28.82 TMC for Krishna Basin. The demand for domestic water is estimated considering 100 LPCD (litres per capita per day). The supply of groundwater by 2020 is assumed to be reduced by 25 per cent.

Table 3.3: Estimated Water Supply and Demand in Karnataka, 2009 and 2020

Item	*2009*	*2020*
Estimated supply	1695 TMC of surface water 485 TMC of groundwater	1975 TMC of surface water 364 TMC of groundwater
Estimated demand	A. Irrigation: 1362 TMC B. Industrial use 33.24 TMC C. Livestock : 57.64 TMC D. Domestic: 93.72 TMC Total: 1547 TMC	
Supply - Demand gap	+ 633 TMC	+ 316 TMC

Note: TMC = Thousand million cubic feet, which can irrigate around 4,000 ha of semi-dry crops or 1000 ha of paddy or 1,600 ha of sugarcane.

Further, irrigation is classified into major, minor and groundwater irrigations including other sources, according to the source of irrigation (Table 3.4). Around 37 per cent of the total area is irrigated by major irrigation and 63 per cent by minor irrigation.

Table 3.4: Water Source, Number of Structures, Total Area Irrigated in Karnataka, 2007

Irrigation Source	*Number*	*Gross Area ('000 ha)*
Major irrigation projects	80	1291
Minor irrigation structures		
a. Tanks	33,217	234
b. Wells	10,75,562	1,772
(i) Dug-wells	4,56,463	4,831
(ii) Tube-wells	6,19,099	1,289
Others	19,954	160
Gross		3,457

Source: Annual Season and Crop Statistics Report, 2007-08, Directorate of Economics and Statistics, Government of Karnataka, Bangalore.

RAINFALL AND CROP PATTERN

The rainfall pattern in Karnataka indicates wide fluctuations in the yearly rainfall (Table 3.5). Clearly, the years 2001 through 2004 were drought years receiving less than the normal rainfall of 1941-90, as the rainfall received ranged from 863 mm in 2002 to 1,194 mm in 2001. The rainfall dropped to 1,167 mm in 2008.

Table 3.5: Rainfall Pattern in Karnataka (mm)

Month	*Normal (1901-1970)*	*1998*	*1999*	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2006*	*2007*	*2008*	*Normal (1941-1990)*
January	3	0	0	3	1	2	0	2	5	0	0	0	2
February	4	0	4	9	1	12	2	1	2	0	0	15	3
March	7	2	1	0	1	2	18	6	3	26	1	129	8
April	37	21	24	28	64	24	37	54	67	17	36	33	38
May	87	47	145	74	42	87	7	178	57	152	62	61	94
June	182	272	230	281	245	179	182	202	239	270	344	172	209
July	285	391	448	309	271	107	205	201	472	356	371	189	289
August	190	262	195	341	233	173	172	193	295	273	350	262	216
September	150	251	117	190	177	80	72	140	210	168	270	161	165
October	134	178	248	169	127	178	166	97	196	74	118	106	136
November	49	47	17	10	30	18	9	22	35	67	19	37	46
December	12	8	2	8	2	1	1	0	3	0	8	2	12
Annual	1139	1479	1431	1422	1194	863	871	1096	1584	1403	1579	1167	1217

Source: Annual Rainfall Reports 1995-2007, Monthly Rainfall Report of DE&S, 2008.

CROP PATTERN

The area under cereals and millets occupies around 45 per cent of the cultivated area, followed by 23 per cent under oilseeds, 16 per cent under pulses, 7.4 per cent under commercial crops (cotton, coconut, tobacco) and 8.8 per cent under fruits and vegetable crops. Thus, food crops occupy 61 per cent of the cultivated area of the state (Table 3.6).

Table 3.6: Cultivated Area Under Crops

No.	*Crops*	*Area (lakh ha)*	*Production (lakh tonnes)*	*Yield (kg/ha)*
1	Rice	14.85	39.99	2834
2	Jowar	15.20	14.79	1024
3	Ragi	9.39	16.56	1858
4	Maize	9.36	28.07	3157
5	Bajra	4.31	3.91	954
6	Wheat	2.53	2.26	943
7	Minor millets	0.52	0.27	542
	Total cereals	*56.16*	*105.85*	*1984*
1	Tur	6.00	4.08	716
2	Bengalgram	4.18	2.38	599
3	Horse gram	2.69	1.29	505
4	Black gram	1.11	0.25	237
5	Green gram	4.01	0.99	260
6	Cowpea & other	0.94	0.32	358
7	Avare	0.87	0.21	234
	Total pulses	*19.81*	*9.51*	*505*
	Total foodgrains	*75.96*	*115.35*	*1598*
1	Groundnut	10.40	5.96	603
2	Sesamum	1.03	0.89	912
3	Sunflower	14.27	6.68	492
4	Castor	0.25	0.26	1095
5	Niger	0.33	0.06	194
6	Mustard	0.07	0.02	270
7	Soyabean	1.33	0.75	590
8	Safflower	0.81	0.62	800
9	Linseed	0.13	0.04	351
	Total oilseeds	28.63	15.27	562
1	Cotton	4.13	5.85*	253
2	Sugarcane	4.16	196.48**	93
3	Tobacco	1.01	0.64	667
	Fruits and vegetables	*10.99*		
	Grand total	*124.88*		

Source: Estimates of Principal Crops in Karnataka for 2005-06 by Department of Economics and Statistics, Govt. of Karnataka, Bangalore & *Agricultural Statistics at a Glance, 2006*, Government of India; Units: *Production of cotton is in lakh bales, **Yield of sugarcane is in tonnes/ha.

IRRIGATION PRACTICES, CROP YIELD, WATER-USE EFFICIENCY

The crops, area irrigated, productivity, consumptive use, common method of irrigation and water use efficiency (WUE) (Table 3.7) indicate that the highest area irrigated is in the paddy crop, followed by sugarcane, maize, groundnut, sunflower, coconut, arecanut, wheat and bengal gram. Flow irrigation is the common method followed, while drip irrigation is emerging as the innovative method for crops like coconut, grapes, mulberry, pomegranate, fig and a few vegetables. The water-use efficiency obtained by dividing the yield obtained per ha by the water used per ha, has given the highest value for cabbage, followed by grapes, brinjal, mulberry and banana. Thus, WUE is higher for fruits and vegetable crops compared to cereals and pulses. Even in value terms this holds good.

Table 3.7: Irrigation Practices, Crop Yield, Water-use Efficiency in Karnataka

Sl. No.	*Crop*	*Area (ha)*	*Productivity (kg/ha)*	*Irrigation in Inches*	*Irrigation Practice*	*Water Use Efficiency = (kgs per acre inch = kg/ ha-cm)*
1	Paddy	10,32,902	2,985	111.15	Flow	26.86
2	Jowar	1,48,906	1,675	29.64	Flow, sprinkler	56.51
3	Ragi	3,85,39	2,250	29.64	Flow	75.91
4	Bajra	4,95,21	819	29.64	Flow, sprinkler	27.63
5	Maize	4,47,042	3,716	59.28	Flow, sprinkler	62.69
6	Wheat	1,42,900	1,251	59.28	Flow, sprinkler	21.10
8	Navane	1,62,25	244	19.76	Flow	12.35
12	Red gram	29,178	464	49.4	Flow, sprinkler	9.39
13	Horse gram	934	335	19.76	Flow	16.95
14	Black gram	1,463	175	29.64	Flow	5.90
15	Green gram	4,691	126	24.7	Flow	5.10
16	Avare	2,824	907	14.82	Flow	61.20
17	Cowpea	12,274	562	24.7	Flow, sprinkler	22.75
18	Other pulses	17,186	299	29.64	Flow	10.09
19	Bengal gram	1,00,456	759	24.7	Flow	30.73
21	Sugarcane	4,79,063	92,000	195.13	Flow, drip	471.48
22	Dry chilli	43,002	1,032	69.16	Flow, sprinkler	14.92
23	Dry ginger	9,135	1,322	76.57	Flow	17.27
24	Turmeric	13,259	5,049	76.57	Flow	65.94
25	Cardamom	859	58	69.16	Flow	0.84
26	Coriander	3,231	150	39.52	Flow	3.80

(Continued)

(*Table 3.7 Contd.*)

Sl. No.	Crop	Area (ha)	Productivity (kg/ha)	Irrigation in Inches	Irrigation Practice	Water Use Efficiency = (kg per acre inch = kg/ha-cm)
27	Garlic	1,672	672	49.4	Flow, sprinkler	13.60
28	Pepper	3,186	214	49.4	Flow	4.33
29	Arecanut	1,54,868	2,250	76.57	Flow, drip	29.38
30	Coconut (Nuts)	2,19,506	4,093	96.33	Flow, drip	42.49
31	Cashew	301	565	49.4	Flow	11.44
32	Mango	9,504	5,218	49.4	Flow, drip	105.63
33	Grapes	12,106	27,313	69.16	Flow, drip	394.92
34	Banana	48,371	19,965	96.33	Flow	207.26
35	Papaya	2,246	2,428	59.28	Flow	40.96
36	Pomegranate	17,467	6,332	59.28	Flow, drip	106.82
37	Lemon	7,982	4,451	49.4	Flow, drip	90.10
38	Guava	3,559	2,915	59.28	Flow, drip	49.17
39	Sapota	10,478	3,782	49.4	Flow, drip	76.56
40	Potato	9,615	9,318	64.22	Flow, sprinkler, drip	145.09
41	Sweet potato	485	8,387	59.28	Flow	141.48
42	Onion	53,534	5,978	59.28	Flow, sprinkler	100.84
43	Brinjal	11,782	9,720	39.52	Flow	245.95
44	Tomato	30,854	10,201	59.28	Flow, drip	172.08
45	Beans	5,622	6,437	39.52	Flow	162.88
46	Cabbage	4,449	20,068	44.46	Flow, sprinkler	451.37
47	Groundnut	2,06,820	799	34.58	Flow, sprinkler	23.11
48	Sesamum	1,155	619	24.7	Flow	25.06
49	Safflower	1,291	782	29.64	Flow	26.38
50	Sunflower	2,15,624	750	34.58	Flow, sprinkler	21.69
51	Soyabean	12,556	780	49.4	Flow	15.79
52	Castor	333	841	24.7	Flow	34.05
53	Linseed	202	322	34.58	Flow	9.31
54	Niger	74	191	24.7	Flow	7.73
55	Rapeseed and mustard	243	267	19.76	Flow	13.51
56	Cotton	55,920	536	69.16	Flow, sprinkler	7.75
57	Mulberry	28,767	20,000	88.92	Flow, drip	224.92

MICRO-IRRIGATION: SUBSIDIES

The State of Karnataka has disbursed subsidies of ₹ 260 crores for 1,64,000 hectares of horticultural crops since 1991-92. The total area under micro-irrigation is 1,64,000 ha forming 10 per cent of the total area under horticulture. The central scheme offers 50 per cent of the cost of micro-irrigation system or a fixed amount, whichever is less as subsidy. Thus, the centre's share is 80 per cent and the state meets 20 per cent. Karnataka is offering in addition, 25 per cent to the already existing 50 per cent of central subsidy programme thus totaling to 75 per cent.

In Karnataka, the drip irrigation programme is implemented by the state Department of Horticulture, while the sprinkler irrigation is implemented by the state Department of Agriculture. A study on the evaluation of micro-irrigation in India (*http://www.ncpahindia.com/articles/article18.pdf*) has indicated that in sprinkler irrigation for groundnut and cotton, the saving in water was to the tune of 35-40 per cent, while that in drip irrigation for horticultural crops (fruit crops), the saving was 40-65 per cent, and for vegetable crops, it was 30-47 per cent. The micro-irrigation has in general resulted in savings of labour for irrigation, weeding and harvesting and has reduced the drudgery. The labour saving was higher for field crops than horticultural crops, especially in weeding and in irrigation. There was reduction in the use of electrical power in pumping due to reduced hours of pumping. As liquid fertilizer was expensive, only 30 per cent of the sample farmers adopted fertigation using soluble urea as the major fertilizer.

According to the report, there was an increase in productivity of crops up to 25 per cent in Karnataka for banana. In addition, the farmers received a price premium of 5-10 per cent due to quality fruits. The programme also resulted in social equity.

The subsidy in Karnataka as mentioned earlier, is 75 per cent (50% from GOI and 25% from the state) and is limited to ₹ one lakh per farm, which includes construction of brick-lined storage tank of 32 m × 29 m × 3 m with 25 lakh litre capacity. Regarding implementation, Karnataka has decentralized by delegating powers to the *Raitha Samparka Kendras* (RSK) and by assigning separate staff for the micro-irrigation scheme. By maintaining the seniority list of farmers, transparency is brought using standardized procedures and practices with time limits for sanction and implementation. Single window system has been created at *hobli* level to redress farmers' grievances. The four per cent VAT on drip irrigation equipment also gets subsidy and in addition, there is exemption of stamp duty on documents used for availing loan for micro-irrigation. The Government of Karnataka has also provided for notarized lease agreement instead of registered lease agreement for the tenant farmers to encourage micro-irrigation for share cropping. However, the support from institutional finance for micro-irrigation schemes in Karnataka is negligible due to the lack of coordination.

The study has reported that the release of subsidy gets delayed by six months to one year. The subsidy fixed during 2006 has not been revised and it covers 42 per cent of the unit cost of micro-irrigation. In the implementation, there has been a lack of commitment on the part of the Department of Minor Irrigation, Department of Mines and Geology (groundwater), Watershed Development Department, Agriculture Department, Panchayat Raj Institutions, as perhaps they have not considered water use efficiency as a crucial factor. In addition, the extension support to micro-irrigation has also been meager. Therefore, the equipment suppliers dominate in providing information and in turn maximize their volume of business. Excessive documentation of maintaining 18 documents for bank finance increases the transaction cost of farmers in general and illiterate farmers in particular (*http://www.ncpahindia.com/articles/article18.pdf*).

The NHM (National Horticulture Mission) has classified Karnataka under the A-category state, as the area under drip irrigation as on 2004 was at least 10,000 ha where the cost of drip irrigation was ₹ 40,000 per ha (Table 3.8).

Table 3.8: Estimated Cost of Installing Drip Irrigation System in Karnataka (₹)

Spacing (m × m)	*Area (ha)*					
	0.4	1	2	3	4	5
12×12	10600	16700	25200	32600	53700	71300
10×10	12100	18000	27700	36000	57900	76900
9×9	12400	22100	35500	55900	61400	81100
8×8	12900	19900	31300	41700	65500	86200
6×6	14400	30200	51200	70300	105800	137400
5×5	15100	32800	56600	83100	117100	150800
4×4	16900	39300	63100	100700	142200	179300
3×3	17900	35600	71400	96100	130800	158300
3×1.5	19700	40200	80500	109700	146100	180900
2.5×2.5	20000	39800	81400	111200	199500	239600
2×2	21300	49800	86400	122700	164900	223400
1.5×1.5	26100	55000	109500	165100	205900	281000
1×1	26500	57600	96500	146500	199900	249200

Source: NHM (http://www.ncpahindia.com/articles/article18.pdf).

In the case of sprinkler irrigation, the financial assistance per farm would be a maximum of ₹ 7,500 per ha. As the sprinkler systems are moveable, one sprinkler set can cover more than one ha by shifting the set periodically. The assistance for sprinkler irrigation is limited to those crops for which drip irrigation is uneconomical. A farmer can avail assistance for sprinkler as well as drip irrigation, depending upon the crop, and the combined area from both should be below five ha per farm. Both sprinkler and drip irrigation subsidies will not be available for a crop on the same plot/field being cultivated by the farmer. In addition, assistance for sprinkler irrigation alone is discouraged, as it is less efficient than the drip system. The estimated cost of sprinkler system is ₹ 13,690 for 63 mm pipe diameter, ₹ 14,270 for 75 mm pipe diameter and ₹ 17,280 for 90 mm pipe diameter.

A farm is eligible for assistance only if adequate water is available for the area proposed to be brought under drip/sprinkler irrigation. The installation of drip/sprinkler irrigation system and the assistance should be limited to the area for which adequate water is available. This scheme does not fund for creating new water sources, the funds for which are available from other programmes such as National Horticulture Mission, IWDS, SGSY, SGRY, IWDP, etc. And the groundwater from wells funded by these agencies, should be used in conjunction with drip/sprinkler irrigation.

ECONOMICS OF MICRO-IRRIGATION (DRIP AND SPRINKLER)

This section is based on the primary data based studies conducted by the graduate students of the Department of Agricultural Economics, University of Agricultural Sciences, Bangalore. As the studies were conducted for different crops at different locations and times, they are discussed separately as under:

Economics of Grapes, Mulberry, Tomato in Eastern Dry Agroclimatic Zone and Arecanut in Southern Transition Agroclimatic Zone of Karnataka

Considering the crop pattern as proportionate to gross irrigated area (GIA), in drip irrigation farms (DIF), area under mulberry formed 44 per cent and area under grapes formed 54 per cent. In conventional irrigation farms (CIF), mulberry formed 52 per cent, followed by 13 per cent under grapes and 11 per cent under tomato in summer and nine per cent under tomato crop in *kharif*. The irrigation intensity was higher in CIF than DIF.

Water-use Efficiency of Different Crops across Drip and Conventional Irrigation

In drip (conventional) irrigation system, 9.05 (3.86) quintals of mulberry (leaves as output), 10.50 (2.85) quintals of grapes and 12.45 (5.03) quintals of tomato were produced per acre-inch of water. The volume of water used per kg of output was lower in DIF (0.023 acre-inch) than CIF (0.057 acre-inch). Thus, drip irrigation is 40 per cent more efficient than conventional irrigation (Table 3.9). Similar results apply to the volume of water used to produce a quintal of output under the two systems.

The economic efficiency of water use is the net return per acre-inch of groundwater used. The net return per acre-inch of water from mulberry, grapes and tomato were higher in DIF (₹ 1,384, ₹ 4,723 and ₹ 2,696, respectively) than CIF (₹ 525, ₹ 769 and ₹ 1,040, respectively). The net return per acre of mulberry, grapes and tomato was higher in DIF (₹ 7,621, ₹ 52,084 and ₹ 26,208, respectively) than CIF (₹ 4,978, ₹ 21,489 and ₹ 22,796, respectively). The net return per acre-inch was higher in arecanut from drip irrigation (₹ 3,186) than conventional method (₹ 818). The net return per acre from arecanut was higher from drip irrigation (₹ 58,237) than conventional (₹ 37,556) irrigaton and also was 200 per cent more efficient than conventional irrigation. The net return per rupee of groundwater from drip irrigation (conventional irrigation) in Mulberry was 2.88 (1.24), in grapes was 12.84 (10.26), in tomato was 2.47 (2.21) and in arecanut was ₹ 14 (11), respectively. Thus, the drip irrigation farms are at least 100 per cent more efficient than conventional irrigation farms (Table 3.9). Mulberry provides the highest efficiency of 232 compared to arecanut (130), grapes (125), and tomato (112).

Table 3.9: Water-use Efficiency Across Different Crops, 2009

Particulars	*Physical Efficiency*		*Economic Efficiency*		
	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 (₹)*
Mulberry					
DIF	9.05	0.11	1,384	7,621	2.88
CIF	3.86	0.26	525	4,978	1.24
Efficiency	234	42	264	153	232
Grapes					
DIF	10.50	0.09	4,723	52,084	12.84
CIF	2.85	0.35	769	21,489	10.26
Efficiency	368	26	614	242	125
Tomato					
DIF	12.45	0.08	2,696	26,208	2.47
CIF	5.03	0.19	1,040	22,796	2.21
Efficiency	248	42	259	115	112
Arecanut					
DIF	50	0.023	3,186	58,237	14
CIF	17	0.057	818	37,556	11
Efficiency	300	40	400	200	130

Note: Efficiency= (DIF/CIF)*100, DIF = Drip irrigation farms, CIF = Conventional irrigation farms.

Profile of Irrigation Wells

Eastern Dry Zone of Karnataka: In DIF area, 64 bore-wells were functioning, whereas in CIF area 45 bore-wells were functioning. Even though the number of wells possessed by farms was higher in DIF than CIF, the proportion of functioning wells was lower in DIF (67%) than CIF (81%). The proportion of well failure was higher in DIF (33%) than CIF (19%). The investment per well was a bit higher in DIF (₹ 1,11,982) than CIF (₹ 1,10,165). Investment per functioning well was 26 per cent higher for farms with drip irrigation (₹ 1,66,223) than conventional irrigation farms (₹ 1,31,551) because of the higher probability of well failure. Hence, even though the modal age of wells in both the situations is the same, as the well failure and the investment per well were higher due to drip irrigation on DIF, the annual negative externality cost is 85 per cent higher on DIF than CIF (Table 3.10).

Table 3.10: Profile of Micro-irrigation in Sample Farms in Karnataka: 2009

Sl. No.	*Particulars*	*Eastern Dry Zone*		*Southern Transition Zone*	
		Drip Irrigation Farms	*Conventional Irrigation Farms*	*Drip Irrigation Farms*	*Conventional Irrigation Farms*
1	Sample farms (No.)	45	45	45	45
2	No. of functioning bore-wells (%)	64 (67)	46 (81)	61 (88)	56 (92)
3	No. of non-functioning bore-wells (%)	31 (33)	11 (19)	8 (12)	5 (8)
4	No. of total bore-wells (%)	95 (100)	57 (100)	69 (100)	61 (100)
5	Average life of prematurely failed wells (years)	9.13	7.09	7.75	1.75
6	Average age of all wells (years)	9.58	8.93	15.2	14.28
7	Modal age of functioning wells (years)	9	9	17	19
8	Depth of bore-wells (feet)	536	570	250	230
9	Yield of well (gallons per hour-GPH)	1,663	1,739	2,676	3,000
10	Year range of wells drilled	1958-2007	1958-2008	1968-2005	1980-2005
11	Earliest year of drip irrigation system installed	2,000	NA	1,985	NA
12	Modal year of drip irrigation	2004	NA	2,000	NA
13	Investment per well in 2008 (₹)	1,11,982	1,10,165	1,03,434	62,730
14	Investment per functioning well in 2008 (₹)	1,66,223	1,31,551	1,16,999	68,331
15	Amortized cost per well in 2008 (₹)	17,350	19,196	10,517	8,259
16	Amortized cost per functioning well in 2008 (₹)	25,754	23,786	11,897	8,997
17	Annual negative externality cost (₹) (16–15)	8,404	4,590	1,380	738
18	Increase in externality in DIF over CIF (%)	83		87	

Note: Figures within the parentheses indicate percentage to the respective totals; NA- Not applicable.

Southern Transition Zone of Karnataka: The total number of wells was 69 in DIF area and 61 in CIF. The number of functioning wells was also higher in DIF (61) than CIF (56). The average age of bore-wells was six per cent higher in DIF (15.2 years) than in CIF (14.28 years). The earliest year of the installation of the drip irrigation system was 1985 and the modal year was 2000. The modal age of functioning well was 17 years in DIF and 19 years in CIF. The average depth of bore-wells was 250 feet in DIF and 230 feet in CIF. The groundwater yield of bore wells was 2,676 GPH in DIF and 3,000 GPH in CIF. Investment per well in DIF was ₹ 1,03,434, whereas it was ₹ 62,730 in CIF. Amortized cost per well was ₹ 10,517 in DIF and ₹ 8,259 in CIF. Annual negative externality cost was ₹ 1,380 in DIF and ₹ 738 in CIF, i.e. higher by about 87 per cent (Table 3.10). Precisely, as the externality was higher, farmers adopted drip irrigation on those farms.

Groundwater Resource Economics Across Agroclimatic Zones of Karnataka

Eastern Dry Zone (EDZ) of Karnataka: The gross irrigated area was 5.49 acres on DIF and 3.34 acres on CIF, higher by 64 per cent. The net irrigated area per farm was also higher in DIF (2.77 acres) than CIF (1.62 acres) (Table 3.11). Groundwater extracted per farm in acre-inches was 60 in DIF and 94 in CIF. This shows that groundwater is saved in drip irrigation to the tune of 36 per cent. Groundwater extracted per well in CIF was 91.62 acre-inch, which is higher than 41.99 acre-inch in DIF. The amortized cost per acre-inch of groundwater used was higher in DIF (₹ 613) than CIF (₹ 259). The net return per acre-inch of groundwater used on CIF and DIF were ₹194 and ₹ 457, respectively. The net return per rupee of irrigation cost was 135 per cent higher in DIF (2.80) as compared to CIF (1.20) (Table 3.11).

Southern Transition Zone (STZ) of Karnataka: The GIA per farm was 7 acres in DIF and 6 acres in CIF. Groundwater extracted per farm in acre-inch was 63 and 171 in DIF and CIF, respectively, a saving of 63 per cent. The average groundwater extracted per functioning well in drip farms was 46 acre-inch, lower than that in CIF (137 acre-inch). The amortized cost per acre-inch of groundwater used was ₹ 257 in DIF and ₹ 66 in CIF. The net return per acre-inch of groundwater used was ₹ 2,834 in DIF and ₹ 650 in CIF. The net returns per rupee of irrigation cost was ₹ 13 in DIF and ₹ 11.67 in CIF, higher by 11 per cent. The net return per acre of gross irrigated area was ₹ 41,640 in DIF and ₹ 29,068 in CIF (Table 3.12).

Table 3.11: Details of Groundwater Irrigation in Eastern Dry Zone and Southern Transition Zone of Karnataka, 2009

Sl. No.	*Particulars*	*Eastern Dry Zone*		*Southern Transition Zone*	
	Farm Type	*Drip Irrigation Farms*	*Conventional Irrigation Farms*	*Drip Irrigation Farms*	*Conventiona l Irrigation Farms*
1	Study area	Chickballapur district		Shimoga district	
2	Major crops grown	Mulberry, grapes, tomato		Arecanut	
3	Number of sample farms	45	45	45	45
4	Number of farms owning functioning wells	45	45	45	45
5	Functioning bore-wells (No.)	64 (67)	46 (81)	61 (88)	56 (92)
6	Non-functioning bore-wells (No.)	31 (33)	11 (19)	8(12)	5(8)
7	Total bore-wells (No.)	95	57	69	61
8	Gross irrigated area (acre)	247	151	312.50	281
9	Gross irrigated area per farm (acre)	5.49	3.34	7	6
10	Gross irrigated area per functioning well (acre)	3.86	3.27	5.12	5
11	Net irrigated area (acre)	125	73	146.5	137
12	Net irrigated area per functioning well (acre)	1.95	1.58	2.40	2.44
13	Net Irrigated area per farm (acre)	2.77	1.62	3.25	3
14	Cropping intensity (%)	198	190	219	216
15	Irrigation intensity (%)	198	206	213	205
16	Groundwater extracted per farm (acre-inch)	60	94	63	171
17	Groundwater extracted per functioning well (acre-inch)	42	92	46	137

Note: Figures within the parentheses indicate percentage to total.

Economic Feasibility of Drip Irrigation

The economic feasibility of drip irrigation (Table 3.12) indicates that net present value at 12 per cent was ₹ 94,831 for DIF and ₹ 33,684 for CIF in EDZ and ₹ 3,36,243 for DIF and ₹ 2,38,696 for CIF in STZ. Thus, it is economically feasible to adopt drip irrigation system in both the zones. Further, the IRR was 18 per cent for DIF and 13 per cent for CIF in EDZ and 27 per cent in DIF and 23 per cent for CIF in STZ. In the Eastern Dry

Zone, CIF with an IRR of 13 per cent almost breaks even with the opportunity cost of capital of 12 per cent. This is also revealed by the discounted benefit cost ratio of 1.43 in DIF and 1.09 for CIF in Eastern Dry Zone, while in the southern transition zone, it was 1.5 for DIF and 1.09 for CIF.

Table 3.12: Economic Feasibility of Drip Irrigation in Karnataka: 2009

Sl. No.	*Agro-Climatic Zone*	*Eastern Dry Zone (EDZ)*		*Southern Transition Zone (STZ)*	
	Particulars	*Drip Irrigation Farms (DIF)*	*Conventional Irrigation Farms (CIF)*	*Drip Irrigation Farms (DIF)*	*Conventional Irrigation Farms (CIF)*
1	Net returns per acre-inch of groundwater used (₹)	1451	340	2,834	650
2	Total cost of cultivation of all crops per farm (₹)	53,093	24,783	84,170	87,566
3	Gross returns per farm (₹)	1,40,362	56,665	2,62,298	1,98,670
4	Net returns per farm (₹)	87,269	31,882	1,78,128	1,11,104
5	Net returns per acre of gross irrigated area (₹)	15,889	9,533	41,640	29,068
6	Net returns per acre of net irrigated area (₹)	28,151	19,721	62,623	43,101
7	Net returns per functioning well (₹)	19,210	17,029	1,31,406	89,280
8	Net returns per rupee of irrigation cost (ratio)	2.80	1.20	13	11.67
9	Discounted benefit-cost ratio at 12 per cent	1.43	1.09	1.50	1.09
10	Net present worth (₹) at 12 per cent	94,831	33,684	3,36,243	2,38,696
11	Internal rate of return (%)	18	13	27	23

Economics of Tomato and Mulberry Crops

In this study, conducted in the eastern dry agro-climatic zone of Karnataka (Sanjeeva, 2008) tomato and mulberry crops have been included under drip and conventional irrigation. In tomato, the cost of production upon inclusion of annualized cost of drip irrigation system (DIS) was marginally lower (₹ 20,762) compared to flow irrigation (₹ 21,145). The cost of irrigation per acre was low in drip irrigation amounting to

₹ 2,682 as against ₹ 3,259 in flow irrigation. The irrigation cost formed 18 per cent of the total cost of production in flow irrigation as against 12 per cent in drip irrigation. Productivity in drip irrigation was also higher (165 quintals per acre) compared to flow irrigation (134 quintals per acre). Water used per acre was lower in DIS (12 acre-inch) than flow irrigation (18 acre-inch) with a saving of 6 acre-inch (around 33%). DIS recorded higher productivity (1,320 kg) per acre inch of water as against flow irrigation (717 kg). Similarly, net returns per acre were also higher in DIS (₹ 29,249) compared to flow irrigation (₹ 23,937). Returns per rupee of investment were higher in DIS (₹ 1.41) than flow irrigation (₹ 1.03) (Table 3.13).

Table 3.13: Crop Productivity in Conventional and Drip Irrigation in Eastern Dry Zone, Karnataka, 2008

(per acre)

Particulars	*Tomato*		*Mulberry*	
	Drip	*Flow*	*Drip*	*Flow*
Cost of cultivation (including irrigation cost) (₹)	20763	21145	11935	9592
Cost of irrigation (₹)	2683	3259	1325	2118
Irrigation cost as per cent of total cost (₹)	12.00	18.00	11.00	22.00
Yield (quintals)	165.11	134.59	96.94	84.51
Water used (inches)	12.50	18.76	6.21	11.48
Production per acre-inch of water (kg)	1321	717	1399	649
Gross value of output (₹)	50011	40083	17247	13704
Net return (₹)	29249	23937	5312	4112
Net return per acre inch of water (₹)	2339	1009	604	358
Net return per kg of output (₹)	1.77	1.41	1.61	1.55
Return to cost (₹)	1.41	1.03	1.45	1.43

In mulberry, the cost of cultivation per acre was higher under drip irrigation system (₹ 11,934) than conventional irrigation system (₹ 9,592). Cost of irrigation per acre was lower in DIS (11% of the total cost) than conventional irrigation (22% of the total cost). Productivity in mulberry was higher in DIS (96 quintals) than CIS (84 quintals). Since the yield was higher in DIS, net return per acre was also higher in DIS (₹ 5,312), compared to CIS (₹ 4,112). Return to cost ratio was higher in DIS (₹ 1.45) than CIS (₹ 1.43) (Table 3.13). Farmers adopted drip irrigation as a coping mechanism for the scarcity of groundwater. Tomato and mulberry were the major crops in which farmers were adopting DIS. In order to adopt DIS for tomato, an investment of ₹ 34,000 (subsidy not considered) is required. Drip irrigation resulted in phenomenal savings in (i) labour cost to the tune of ₹ 28,125, and (ii) 6 acre-inches of groundwater worth ₹ 1,122. The net profit per year from adopting drip system over conventional flow irrigation system was ₹ 35,123, indicating the feasibility of adopting drip system in tomato.

Financial Feasibility of Drip Irrigation and Flow Irrigation Through Additional Well

The IRR for drip method was 21 per cent, which is higher than that in flow irrigation with additional well (12 per cent). The NPV was positive and impressive at ₹ 1,16,369 at a discount rate of five per cent in drip method; the same was ₹ 24,980 for flow irrigation with additional well, indicating economic worth of investment on drip method, over additional well. The results indicated that the discounted cost-benefit ratio was more than one (1.95) in drip method revealing feasibility of the investment on drip system, while discounted cost benefit ratio for additional well showed the value which was less than the drip adoption (1.14) (Table 3.14).

Table 3.14: Financial Feasibility of Drip Irrigation System versus Flow Irrigation with Additional Bore-well, 2008

Particulars	*Drip Irrigation System*	*Additional Bore-well*
IRR (%)	21	12
NPV (₹) at 5 per cent	1,16,369	24,980
Discounted benefit-cost ratio	1.95	1.14

Economics of Pomegranate and Fig Crops under Drip Irrigation

The study conducted in Hiriyur taluk in the Central Dry Zone of Karnataka (Prakashkumar, 2002) covered all the 48 farmers who had cultivated fig and pomegranate crops, 88 per cent of whom had adopted drip irrigation. The costs and returns have been upscaled at the rate of 2 per cent to the year 2009. The average size of holding was 13.27 acres. About 30 per cent of the area was occupied by pomegranate, 13 per cent by fig and 29 per cent by coconut (Table 3.15). The proportion of farmers cultivating pomegranate was 58 per cent, cultivating fig was 19 per cent and those cultivating both the crops was 23 per cent. The average area under fig was 4.7 acres, pomegranate was 5.47 acres and both fig and pomegranate was 8.04 acres. With a total of 226 wells in the sample, 118 wells had failed and only 108 were functional, registering a high well failure rate of 52 per cent. Thus, every farm on an average had around five wells of which two were functioning and three had failed. About half of the farmers indicated that they had shifted to drip irrigation due to water scarcity and 21 per cent indicated that it was due to economic scarcity of labour. The average age/life of wells ranged from 10 years to 14 years.

Table 3.15: Crop Pattern of Farmers Cultivating Pomegranate and Fig in Hiriyur Taluk, Karnataka (acres)

Crops	*Cropped Area*	*Percentage*
Coconut	211	29.4
Pomegranate	206	28.8
Fig	94	13.1
Papaya	68	9.5
Sputa	43	6
Mango	37	5.2
Sweet lime	18	2.5
Guava	8	1.1
Jasmine	6	0.8
Arecanut	5	0.7
Other crops	21	2.9
Total	*717*	*100*

The average investment on drip irrigation per farm was ₹ 2,12,643 and farmers availed a subsidy of 47 per cent. The cost per acre-inch of groundwater was ₹ 205 (Table 3.16).

Table 3.16: Economics of Drip Irrigation in Pomegranate and Fig Farms of Hiriyur Taluk in Karnataka

Particulars	*Overall*
No. of drip farmers	42
Investment on drip irrigation per farm (₹)	2,12,643
Own investment on drip irrigation per farm (₹)	1,11,800 (53 %)
Borrowed investment on drip irrigation per farm (₹)	1,00,842 (47%)
Percentage of subsidy	47
Amortized cost of drip irrigation per farm (₹)	22,572
Amortized cost of drip irrigation per acre (₹)	1,576
Amortized cost per acre-inch of water (₹)	205
Age/life of irrigation well (years)	10.10 to 14.13

The discounted cash flow analysis of drip irrigation indicated (Table 3.17) that the discounted benefit cost ratio was 1.30 on pomegranate farms and 1.14 on fig farms, yielding a net present value of ₹ 64,902 per acre from pomegranate and ₹ 31,517 per acre from fig crops,with an IRR of 31 and 28 per cent respectively. The net returns per acre inch of groundwater is ₹ 860 in fig and ₹ 2,068 from pomegranate. The results vary widely across areas as the cost of groundwater varies directly with the probability of well failure, investment on wells and inversely with the average age/life of irrigation well(s).

Table 3.17: Evaluation of Investment on Drip Irrigation in Pomegranate and Fig Crops (₹/acre)

Particulars	*Pomegranate*	*Fig*
1. Discounted costs	2,15,611	2,23,139
2. Discounted returns	2,80,513	2,54,656
3. BCR (ratio)	1.30	1.14
4. Net present value	64,902	31,517
5. IRR (%)	30.99	2,7.86
6. Net returns (₹)	45,504	19,792
7. Groundwater used per acre (in acre-inches)	22	23
8. Net returns per acre-inch of groundwater	2,068	860
9. Net returns per rupee of groundwater	10	4.19

Another study (Nagaraju, 2002) on the economics of fig and pomegranate in drip irrigation, in Hagaraibommanahally, Karnataka, indicated that farmers had formed an association called "Pomegranate Growers Marketing Society" in Hospet and were successfully exporting pomegranate to Singapore, Malaysia and Dubai. They were also marketing their produce to Tamil Nadu, Delhi, Maharashtra and West Bengal. The acute scarcity of groundwater was the main reason for using drip irrigation. The NPV was ₹ 34,727 per acre in the case of pomegranate and ₹ 28,725 per acre in fig. The discounted benefit cost ratio was 2.17 for fig and 1.11 for pomegranate; the IRR was 40 per cent for fig and 21 per cent for pomegranate and the net return per rupee of groundwater cost was ₹ 35 for fig and ₹ 20 for pomegranate. The discount rate used was 14 per cent.

Economics of Drip Irrigation in Rehabilitated and Non-Rehabilitated Tank Irrigation Commands

The tank rehabilitation programme undertaken by Jala Samvriddhi Yojana Sangha, funded by the World Bank in Karnataka, was evaluated (Thamanadevi, 2008) in Eastern Dry Agro-climatic Zone. The sample farmers were chosen from Kolar district. The study indicated a negative externality (quantified as the difference between amortized cost per functioning irrigation well minus amortized cost per irrigation well) was higher among drip irrigation farms which necessitated the adoption of drip irrigation system (at a cost of ₹ 10,029 per well in tank rehabilitation command and ₹ 33,938 per well in non-tank rehabilitation command). The net returns per acre-inch of groundwater used in tank rehabilitated command under drip irrigation were ₹ 588 and ₹ 248 under conventional irrigation. In the non-tank rehabilitated command, these were ₹ 466 and ₹ 142, respectively, i.e. higher than conventional irrigation. The net return per rupee of irrigation cost was also higher for drip irrigation (4.23 and 3.02) compared to conventional irrigation (3.38 and 2.82) in the two situations.

The net returns from crops on drip irrigation and conventional irrigation indicated that all the economic parameters such as net returns per acre, net returns per acre-inch of groundwater, net return per kg of output, cost per kg of output and output per acre were favourable to the farmers using drip irrigation across all crops in tank rehabilitated and non-rehabilitated tank commands in the Eastern Dry Agroclimatic Zone (Tables 3.18 and 3.19). Thus, there was economic supremacy of drip irrigation over conventional irrigation.

Table 3.18: Net Returns from Crops Cultivated using Drip and Conventional Irrigation Methods in Tank Rehabilitated Command in Eastern Dry Zone, Karnataka, 2008

Particulars	*Irrigation Type*	*Paddy*	*Tomato*	*Potato*	*Mulberry*	*Cabbage*	*Cauliflower*	*Banana*
Net returns per acre (₹)	CIF	3112	15748	19218	3551	13479	11361	NC
	DIF	NC	35473	34987	4319	NC	NC	34782
Net returns per acre-inch of water (₹)	CIF	78	777	861	393	779	679	NC
	DIF	NC	3856	3232	794	NC	NC	1764
Net returns per rupee of water (₹)	CIF	0.74	3.30	6.25	3.07	4.94	4.83	NC
	DIF	NC	5.41	19.79	3.19	NC	NC	8.16
Net returns per kg of output (₹)	CIF	1.53	1.27	1.60	0.91	1.14	0.97	NC
	DIF	NC	2.00	1.75	0.94	NC	NC	487
Output per acre-inch of water (kg)	CIF	51	610	538	432	681	698	NC
	DIF	NC	1929	1848	844	NC	NC	487
Cost per kg of output (₹)	CIF	4.84	2.69	2.63	2.61	2.64	1.96	NC
	DIF	NC	1.86	1.43	2.12	NC	NC	1.38
Output per acre (kg)	CIF	2028	12356	12000	3900	11788	11684	NC
	DIF	NC	17750	20000	4589	NC	NC	9600

Note: CIF = Conventional irrigation farms; DIF = Drip irrigation farms; NC = Not cultivated

Table 3.19: Net Returns from Crops Cultivated using Drip and Conventional Irrigation Methods in Non-rehabilitated Tank Command in Eastern Dry Zone, Karnataka, 2008

Particulars	*Irrigation Type*	*Paddy*	*Tomato*	*Potato*	*Mulberry*	*Onion*
Net returns per acre (₹)	CIF	2722	14090	10447	4811	10693
	DIF	NC	NC	34824	9712	NC
Net returns per acre-inch of water (₹)	CIF	84	747	449	556	779
	DIF	NC	NC	3620	2248	NC
Net returns per rupee of water (₹)	CIF	0.44	2.07	1.38	1.61	4.60
	DIF	NC	NC	2.54	3.57	NC
Net returns per kg of output (₹)	CIF	1.29	1.25	0.98	1.04	1.98
	DIF	NC	NC	2.27	1.96	NC
Output per acre-inch of water (kg)	CIF	65	597	459	535	393
	DIF	NC	NC	1594	1149	NC
Cost per kg of output (₹)	CIF	4.76	1.90	2.83	2.08	2.08
	DIF	NC	NC	2.13	1.72	NC
Output per acre (kg)	CIF	2105	11261	10667	4629	5400
	DIF	NC	NC	15333	4962	NC

Note: NC: Not cultivated, CIF: Conventional irrigation farm, DIF = Drip irrigation farm.

OUTREACH: POTENTIAL FOR EXPANSION AND CONSTRAINTS

For outreach, there is a need to identify the crucial variable/s on which the extension services have to be provided. Towards this endeavour, stepwise discriminant function analysis was performed. In the Eastern Dry Zone of Karnataka, out of the six variables considered for the analysis, the cropping intensity, water used in acre-inches and net returns per acre-inch of water were the three crucial variables favouring the adoption of drip irrigation (Table 3.20). With the Mahalanobis D^2 of 646.79, the Discriminant function was significant (Priyanka, 2009), displaying a canonical correlation of 0.919, the square of which (0.84) indicated that 84 per cent of the variation in the dependent variable (*the method of irrigation*) could be explained by three independent variables, namely cropping intensity, water used in acre-inch and net returns per acre inch of water. The major variable among these three variables was *net returns per acre-inch of water* and this accounted for 98.75 per cent of the total distance between drip and conventional irrigation farms.

Table 3.20: Factors Discriminating Drip Irrigation Farms (DIF) and Conventional Irrigation Farms (CIF): Step-wise Discriminant Function Analysis for Eastern Dry Zone, Karnataka, 2009

Sl. No.	*Discriminating Variable*	*Discriminating Co-efficient (L_i)*	*Group Mean Value*		$L_i(d_1\text{-}d_2)$	*D^2 = 646.79 Percentage Contribution*
			DIF (d_1)	*CIF (d_2)*		
1.	Cropping intensity	0.803	268	265	2.409	0.37
2.	Groundwater used in acre-inches	0.283	23	43	5.666	0.88
3.	Net returns per acre-inch of groundwater	0.142	5462	964	638.716	98.75

A similar analysis was carried in the Southern Transition Zone of Karnataka (Mamatha, 2009). The discriminant function was found highly significant with the Mahalanobis D^2 of 1,064.24, and canonical correlation of 0.741, the square of which (0.55) indicated that 55 per cent of the variation in the *method of irrigation* could be explained by the discriminant function. The major variable was *net returns per acre-inch of groundwater*, as this accounted for 99 per cent of the total distance between the groups (Table 3.21).

Table 3.21: Factors Discriminating Drip Irrigation Farms (DIF) and Conventional Irrigation Farms (CIF): Step-wise Discriminant Function Analysis for Southern Transition Zone, Karnataka, 2009

Sl. No.	*Discriminating Variable*	*Discriminating Co-efficient (L_i)*	*Group Mean Value*		$L_i(d_1\text{-}d_2)$	*D^2=1,064.24 Percentage Contribution*
			DIF (d_1)	*CIF (d_2)*		
1.	Net returns per acre-inch of groundwater	0.850	3800	2548	1064.20	99
2.	Net returns per rupee of water	0.033	17.3	16	0.04	1

Thus, the net return per-acre inch of groundwater which is highest in the case of drip irrigation compared to conventional irrigation plays the key role in adoption of drip irrigation. An analysis of the marginal productivity of groundwater has further illustrated the importance of the method of irrigation in shaping the marginal productivity.

Marginal Productivity of Groundwater-use in Drip and Conventional Methods of Irrigation

For the Eastern Dry Zone, the net returns per farm were regressed on water used per farm for irrigation and intercept and slope dummy variables (0 for conventional and 1 for drip (intercept dummy D_1 and slope dummy D_1X). The results provided the following function:

$$Y = 15292 + 465X + 9{,}911D_1 + 1{,}960D_1X$$

t values (1.41) (2.45) (0.72) (6.17);

Adj $R^2 = 0.56$, $R^2 = 0.76^{**}$, F = 36, n = 81

For DIF, the threshold net return was ₹ 15,292 per farm, equivalent to return from inputs other than irrigation water. The marginal productivity of groundwater was ₹ 465 per acre-inch at any level of use. Due to drip irrigation, the threshold net return per farm got shifted by ₹ 9,911. Hence, the threshold net return per farm due to drip irrigation = ₹ 15,292 + ₹ 9,911 = ₹ 25,203. The marginal productivity of the drip method of irrigation = ₹ 1,960. The marginal productivity of the groundwater applied through drip irrigation = ₹ 465 + ₹ 1,960 = ₹ 2,425. The estimated net return per DIF farm at the average level of use of groundwater = ₹ 15,292 + 465 (60) + 9,911 (1) + 1,960(1) (60) = ₹ 1,70,703. *The estimated net return per farm in CIF = (₹) 15,292 + 465 (94) = ₹ 59,002. Thus, Y = 25,203 + 2,425 X is discerned for DIF and Y = 15,292 + 465X is for CIF.* Using the similar procedure, the following results were obtained for arecanut farmers in the Southern Transition Zone:

$$Y = 47{,}762 + 546X + 12{,}524D_1 + 13{,}14D_1X$$

t value (2.49) (4.12) (0.39) (2.31),

Adj $R^2 = 0.26$, $R^2 = 0.29^{**}$, F = 10, n = 90

The threshold net return was ₹ 47,762 per farm, the return to inputs other than irrigation water. The marginal productivity of groundwater was ₹ 546 per acre-inch at any level of use. The marginal productivity of the drip method of irrigation was ₹ 1,314. The marginal productivity of groundwater applied through drip irrigation = ₹ 546 + ₹ 1,314 = ₹ 1,860. The threshold net return per farm got shifted by ₹ 12,524 due to drip irrigation. The estimated net return for DIF was 47,762 + 546 (63) + 12,524(1) + 1,314 (1)(63) = ₹ 1,77,466. The estimated net return for CIF was ₹ 47,762 + 546 (171) = ₹ 1,41,128. Thus, Y = 47,762 + 546 X was discerned for CIF and Y = 60,286 + 1,860 X was discerned for DIF.

In order to model the investment on coping mechanism, investment on drip system was Tobit regressed on independent variables such as net return per farm (₹) and water used in acre-inches per farm. Here, investment on drip irrigation was the actual cost of drip irrigation for drip farms, while it became zero for farms with conventional irrigation. The willingness to pay for drip irrigation was estimated using the Tobit maximum likelihood model where at least one value for dependent variable should be zero . The results (SAS output) (Table 3.22) for the Eastern Dry Zone of Karnataka indicated that the variables, net return per farm (₹) and water used in acre-inches were significant at five per cent and one 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 ₹ 933. The minimum investment for drip irrigation was ₹ 10,262 per farm. The average drip investment per farm was ₹ 41,115. 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 which has reflected in motivating farmer to invest ₹ 932 on drip irrigation for every one acre-inch of groundwater saved in the process of adoption of drip irrigation.

Table 3.22: Modeling Investment on Drip Irrigation System in Karnataka Dependent Variable: Investment on Drip Irrigation (₹) (Tobit Regression) (Zero for Conventional Irrigation Farms and Actual Investment on Drip Irrigation Farms)

Variable	*Coefficient*	*Standard Error*	*t-value*	*Coefficient*	*Standard Error*	*t-value*
	Eastern Dry Zone, Karnataka			*Southern Transition Zone, Karnataka*		
Intercept	10,262**	5.12	1967	3,688	0.52	7,000
Net return per farm (₹)	0.23*	0.10	2.22	0.22**	0.017	12.85
Water use (acre-inches) per farm	–932.96**	247	–3.77	–354.2**	47.98	–7.38
Number of observations			68			90
log likelihood function (Tobit)			–401			–522

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

Thus, for outreach, it is crucial to impress upon the farmers that net returns per acre-inch of groundwater will be higher in the drip irrigation method than the conventional irrigation method. The potential for expansion lies through the usage of such crucial variables for diffusion of drip method of irrigation.

Scope for Micro-irrigation in Karnataka

Largely, the current micro-irrigation technology is applicable for broad-spaced crops. Therefore, the progress in micro-irrigation has largely been for perennial crops which are usually broad spaced. The possibilities of expansion of drip and sprinkler irrigation indicate that the potential exists for perennial crops like coconut, followed by arecanut, mulberry, mango, pomegranate and grapes. In addition, among the annual crops, sugarcane tops in expanding the area under drip irrigation. Among seasonal crops, maize tops followed by cotton and among vegetables, tomato tops in expanding the area for drip irrigation (Table 3.23). The studies in Karnataka have demonstrated that the natural resource economic factor namely the *net return per acre-inch of groundwater* is the crucial variable for the adoption of drip irrigation and this is influenced by the economic scarcity of groundwater. Of late, the scarcity of labour is also motivating the farmers to adopt drip irrigation.

Table 3.23: Scope for Micro-Irrigation in Karnataka

Sl. No.	Micro-Irrigation	Current Area (ha)	Potential Area (ha)	Drip/ Sprinkler Cost (₹/ha)	Subsidy Level (%)	Yield Increase (%)	Water Saving (%)
Crops Under Drip Irrigation							
1	Coconut	65,852	1,31,704	58,442	50 to 70	25	33
2	Arecanut	38,717	77,434	35,000	50 to 70	30	38
3	Mango	6,286	9,504	25,000	50 to 70	25	40
4	Grapes	3,983	12,106	44,000	50 to 70	45	40
5	Sputa	1,139	2,619	35,000	50 to 70	42	48
6	Mulberry	28,767	47,180	43,400	50 to 70	36	42
7	Tomato	1,542	7,713	34,000	50 to 70	10	56
8	Potato	480	1,923	40,500	50 to 70	15	30
9	Pomegranate	4,367	10,000	35,000	50 to 70	30	40
10	Sugar cane	5,000	65,527	30,000	50 to 70	25	40
Crops Under Sprinkler Irrigation							
1	Bajra	990	2,476	25,000	50 to 70	19	56
2	Cabbage	88	222	30,000	50 to 70	3	40
3	Chillies	860	2,150	35,000	50 to 70	24	33
4	Cotton	1,118	2,796	40,000	50 to 70	50	36
5	Cowpea	245	613	25,000	50 to 70	3	19
6	Garlic	33	83	35,000	50 to 70	6	28
7	Red gram	583	1,458	30,000	50 to 70	57	69
8	Groundnut	4,136	10,341	25,000	50 to 70	40	20
9	Jowar	2,978	7,445	25,000	50 to 70	34	55
10	Maize	8,940	22,352	35,000	50 to 70	36	41
11	Onion	1,070	2,676	35,000	50 to 70	23	33
12	Potato	192	480	30,000	50 to 70	4	46
13	Sunflower	4,312	10,781	25,000	50 to 70	20	33
14	Wheat	2,858	7,145	25,000	50 to 70	24	35

Constraints and their Management

Drip irrigation and groundwater are appearing as an indispensable technology-natural resource complement. However, there is no professionalism in the irrigation management service in the public/private sector to address the economic scarcity of groundwater together with irrigation literacy. Even with that gap, drip irrigation is expanding, but at a slow pace in the state. With the acceleration of groundwater irrigation literacy, which should include the nature of the resource, groundwater divining, groundwater recharge, the right depth upto which a well should be drilled, the safe and wise isolation distance to be maintained for sustainable extraction, the right horsepower of the pump and the number of stages to be installed at the right depth in the well, the right quality of pumpset, the right crop pattern for the soil type, and the choice of drip system, with the right discharge, laterals, are all crucial to be imparted on a regular basis to the farmers. It should also include how to clean up the clogs in the drip system and how to set it right so that the farmers would be able to attend to the system with accuracy. The Karnataka Groundwater Regulation and Control Bill which is yet to be passed by the legislature, needs to consider providing impetus for adoption of drip and sprinkler systems by linking the assistance to farmers under several developmental programmes on a preferential basis to farmers who have adopted micro-irrigation. This will motivate other farmers who are still using conventional methods to move towards micro-irrigation and appreciate the economic value of groundwater.

CONCLUSIONS AND IMPLICATIONS

Farmers who have undertaken drip irrigation are those who have suffered by high failure of wells and with the lowest average age of irrigation wells. The negative externality defined as the difference between amortized cost of irrigation per functioning well and the amortized cost of irrigation per well is the highest for farmers with drip and flow irrigation, followed by farmers who have rebored and/or those having additional wells in addition to the existing well and farmers with existing irrigation wells. Thus, farmers who have faced the highest negative externality are those who are adopting drip irrigation to reduce the negative externality. This action is reflected in almost equal amortized cost per acre-inch of groundwater for drip irrigation (₹ 556) farmers and for farmers with existing well(s) who are not coping with groundwater scarcity (₹ 557). Thus, drip irrigation brings the cost of groundwater on par with farmers who are not coping with groundwater scarcity, but with fairly assured water for irrigating crops. Thus, considering all crops, net return per acre is the highest for drip irrigation farmers (₹ 21,240), followed by farmers with the existing low-yielding irrigation wells (₹ 9,573) and farmers who have invested on deepening of existing well(s) or drilling of additional well(s) (₹ 5,613), which are risky ventures. Thus, the net return per rupee of irrigation cost which reflects the economic efficiency of groundwater used in different coping mechanisms adopted by farmers, is the highest for drip irrigation (₹ 3.20), followed by farmers not following any coping mechanism (₹ 1.40). The least water-use efficiency is for farmers who have drilled additional well or who have deepened, since they are concentrating on extraction (supply side) rather than on water-use efficiency (demand side). Farmers using drip irrigation in transition