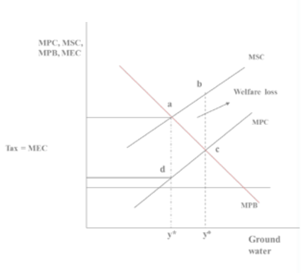
September 2019

POLICY BRIEF - 29

Are Farmers Subsidizing the Cost of Irrigation to Consumers? Evidence from a micro study in Karnataka

MG Chandrakanth[1], Kiran Kumar R Patil[2]



Introduction

Karnataka has around 25 lakh irrigation wells with more than 70 % of them being borewells. The water pumped out, as well as water recharged are both estimates, and vary with methodology used. Probability of well success is usually measured using the Negative Binomial Distribution (NBD). Recent estimates reveal that NBD probability of success of borewell is 0.3, due to high rate of initial and premature failure of borewells. In order to obtain a successful well, farmer has to drill three wells of which one may function and two may fail. Also, dug wells / open wells numbering around three lakhs in the state have already dried up.

More than 85% of water is utilized by irrigation in India referred to as 'consumptive use', which implies that once water is applied to crops, it cannot be recovered. Water use for domestic / industrial purposes is 'non-consumptive use', where water is recoverable as waste water /sewage water. About 70 % of irrigation is met by groundwater and 30 % is met by surface water in India. Hard rock areas of India constitute 65% of geographical area where recharge is less than 5 to 10% of rainfall. These areas also constitute India's highest demand for groundwater resource. Therefore water use discipline should come first from agriculture / irrigation.

Climate change and groundwater

During 1950 - 1965, the Pre green revolution period, surface water through tanks, canals were major sources of irrigation. Green revolution period: 1965 - 1980, with million wells scheme, thousand wells scheme, promoted rapid exploitation through shallow dug wells attached with manual lifts - Yetha, Kapile, Picota, Persian wheel (bucket machine) for extracting water supporting subsistence irrigation. During 1980 - 1990: Dug-cum-borewells in operation with around 5 HP centrifugal pumps lifting water, and gradually wells were drilled deeper - to cultivate - paddy, vegetables etc. Well failure began surfacing. Period 1990 - 2000 witnessed shallow bore wells with submersible pumpsets of 5 to 10 HP capacity for paddy, maize, sugarcane, vegetables. Rate of well failure increased. Post 2000, witnessed deep borewells with pumpsets of more than10 HP with micro irrigation, experiencing well failure of 70 percent through initial failure, premature failure of borewells.

Conceptual framework

According to Baumol and Oates (1988)[3], the six conditions for the presence of externality are that (1) action of one agent should result in an unintended side effect on another agent (2) this action should enter into production / consumption function of another agent (3) should result in inefficiency (4) welfare loss and is not regulated by (5) price mechanism or by (6) institutions. The reciprocal externality (Partha Dasgupta, 1982)[4] indicates that one irrigation well drilling deeper / extracting higher volume of groundwater will influence the yield of other wells, and similar to non-point pollution, difficult to locate well/s responsible for the influence. Studies have indicated that the probability of initial, premature failure of irrigation wells is increasing and currently farmers in many areas, drill at least three wells to obtain a functioning well, as the probability of well failure has reached 0.7[5]. Over-extraction of groundwater is resulting in increasing probability of initial /premature failure/s of irrigation well/s, along with reduced yield of water, reduced area irrigated on other farmers' field.

Farmers by violating isolation distance between wells, impose externality on neighboring farmer/s. Thus the cost of extraction of groundwater is = Marginal cost MC of extraction + Opportunity cost incurred by neighboring farmer/s due to over extraction by the farmer. Thus, the farmer imposes a social cost on neighboring farmer/s forcing neighbor to drill deeper, or use higher capacity pump or forced to drill additional well. This is externality measured as Marginal Externality Cost given by the difference between Marginal Social Cost (MSC) and the Marginal Private Cost (MPC). As the farmer is not bearing this MEC, he is extracting y^o, which is determined by the point where his Marginal Private Benefit MPB = his marginal cost of extraction MC. However farmer should have extracted only y^* which is the socially optimal where MPB = MSC. Thus, farmer (and the society) both ignore this negative externality which is a social cost. And this results in (i) inefficiency given by over extraction = $y^o - y^*$ and (ii) welfare loss = the triangle abc (Fig 1). The extent of internalization of externality varies with farmers by way of adopting micro irrigation technologies, groundwater recharge, cultivating low water, high value crops, sharing well water in water markets.

Borewell recharge structure by Chitradurga farmer

---

1 Prof. M.G. Chandrakanth, Director, Institute for Social and Economic Change, Bengaluru

2 Dr Kiran Kumar R Patil, Assistant Professor (Contractual), Department of Agricultural Economics, University of Agricultural and Horticultural Sciences, Shimoga

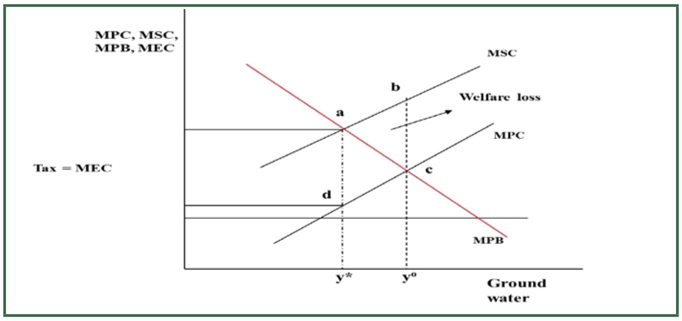
3 Baumol, W. J. and Oates, W. G.,1988, The theory of environmental policy, second edition, Cambridge University press, pp: 17-18

4 Dasgupta, Partha, 1982, The control of resources, Cambridge, MA: Harvard university press.

5 (1) Kiran Kumar R Patil, Economics of coping mechanisms in Groundwater irrigation: role of markets, technologies and institutions, Unpublished PhD thesis, Department of Agricultural Economics, University of Agricultural Sciences, Bangalore, 2014, (2) Nagaraj, N, Chandrakanth, M.G. and Gurumurthy, 1994, Borewell failure in drought prone areas of Southern India: A case study, Indian Journal of Agricultural Economics, 49(1), Jan-Mar, 102-106.

Editor: S. Manasi

Fig 1: Negative Externality Leading to Overextraction of Groundwater



Notes: MSC = Marginal Social cost due to over extraction of groundwater, MPC = Marginal Private cost of extracting groundwater, MPB = Marginal private benefit from Groundwater irrigation, MEC = Marginal Externality Cost = MSC – MPC; Inefficiency = y^o-y^*; Welfare loss = y^*y^oca - y^*y^oba

Why accounting for groundwater cost is crucial

Every input used in the production process needs to be valued / priced. Groundwater is extracted / pumped by farmers, and as electricity is provided free, farmers think that groundwater is free. But more than 70 percent of the cost of groundwater is borne by farmers due to frequently drilling of wells necessitated by frequent well failures. This way they are net subsidizing consumers instead of receiving subsidies. With 65% of geographical area of India being hard rock area with poor recharge (of 5-10% of rainfall), where groundwater irrigation dominates, it is crucial to properly account for cost of groundwater resource

Empirical framework

Estimation of reciprocal negative externality is the key for this study and this needs knowledge on different types of wells and costs considered. Thus, four types of borewells are discernible : (1) Borewells with initial failure (or borewell/s which do/did not yield any groundwater at the time of drilling and thereafter); (2) Borewells with subsistence life (or borewell/s which yielded groundwater for the number of years equivalent to the Pay Back Period (PBP)[6]; (3) Wells with premature failure (borewell/s which served below subsistence life or the PBP); and (4) Wells with economic life/age (borewell/s which function or yield groundwater beyond the PBP).

Reciprocal Externality

The existence of externality in hard rock areas, is indicated by the presence of well failure. Thus, if a farmer does not have any failed well, s/he has not suffered externality. However, if a farmer has failed well/s, then this failure is due to negative externality caused by cumulative interference effects of irrigation wells. Therefore where the farmer suffers from well failure/s, the amortized cost per functioning well will be higher than the amortized cost per well (given by the amortized cost on all wells divided by the total number of wells (i.e. including both functioning and nonfunctioning wells). The externality per well is thus estimated as = [(Amortized investment on drilling and casing of bore- wells over the subsistence life of well/s or economic life of well/s whichever is relevant) ÷ [number of wells which served PBP + number of wells serving economic life)] minus [(Amortized investment on drilling and casing of bore-wells over the subsistence life of well/s or economic life of well/s whichever is relevant)] ÷ [Number of all types of wells on the farm].

If A = (Amortized investment on drilling and casing of borewells of initially failed wells and wells which served for PBP) divided by all wells on the farm; B = (Amortized investment on drilling and casing of borewells of initially failed wells and wells which served for PBP) by the number of functioning borewells on the farm, then Externality per borewell = (B-A). If B = A, no externality exists, thus, externality = 0, as all wells are functioning on the farm. If B >A, negative externality exists. The externality on each groundwater irrigation farm is assumed as equal to the amortized investment per functioning well minus amortized investment per well. If all wells are functioning on the farm, there is no externality. The basis of the hypothesis is that all wells in hard rock areas succumb to cumulative interference among irrigation wells.

Chrysanthemum, low water intensive high value crop grown by shared well farmers and control farmers in Chitradurga district

Variable cost of groundwater

The variable cost of groundwater irrigation includes, amortizing the investment on drilling and casing of bore wells over the subsistence life of bore well/s or economic life of bore well/s (whichever is relevant for the specific farmer) plus the operation and maintenance costs of the bore well. The amortized investment is divided by the volume of groundwater extracted to obtain the variable cost of groundwater per acre-inch.

Fixed cost of groundwater

The fixed cost of groundwater irrigation includes, amortized investment on irrigation pump sets, pump house, electrification charges, groundwater storage structure (constructed if any), groundwater delivery pipe investment, drip irrigation and accessory investment for a period of 10 years. The amortized fixed investment is divided by the volume of groundwater extracted in the recent year to obtain the fixed cost of groundwater per hectare centimeter or acre-inch. The fixed cost of groundwater recharge structure if any, is obtained by amortizing the investment on groundwater recharge over the subsistence or economic life of bore- well, whichever is relevant for the bore well.

Life and Age of irrigation borewells

Life of irrigation bore well refers to the number of years a borewell functioned or yielded water. Age of irrigation borewell refers to the number of years the borewell is serving at the time of field data collection. For instance, if we collected field data in 2018, if a farmer has four borewells : Borewell A drilled in 2010 and suffered initial failure), B drilled in 2013 and functioned upto 2016, C drilled in 2017 and is still functioning, D drilled in 2015 and is still functioning, then the life of well A was 0 years, life of well B was 4 years, age of well C is 2 years, age of well D is 4 years. For this farmer, the Average age or life of borewell = (0+4+2+4= 10)/4 = 2.5 years. The Average age or life was considered because, amortization of investment with time t = 0, leads to infinity.

Choice of discount rate

The choice of discount rate is puzzling in evaluation of public policies and programmes. Lind (1997) discusses regarding the choice of discount rate which can be in the range of 5 to 10 percent or 0 to 3 percent[7]. Diwakara and Chandrakanth note the debate among economists Pearce *et al.* (2003), Weitzman (1998), and Gollier (2002) on the social discounting and note the inverse relationship of discount rate with time[8]. Further they indicate that the rate of growth of nominal investment in irrigation wells in different parts of Karnataka was (i=) two per cent by considering the vintage of irrigation wells drilled / dug by farmers. In this study too, from the sample data, investment on earliest well (IEW) and the investment on latest well (ILW) were used to solve the rate of interest using IEW $(1+i)^n$ = ILW. Upon

---

6 The Payback period refers to the period involved in recovering the total investment on drilling, casing, irrigation pumpset, conveyance structure, storage structure, drip / sprinkler structure, recharge structure, electrification charges of borewell, from the annual net returns on the farm.

7 Lind, R.C. (1997), 'Intertemporal equity, discounting, and economic efficiency in water policy evaluation', Climatic Change 37: 41–62. H Diwakara and MG Chandrakanth, 2007, Beating negative externality through groundwater recharge in India: a resource economic analysis, Environment and Development Economics, Cambridge University Press, Vol. 12, pp. 271–296.

8 (1) Pearce, D., B. Groom, C. Hepburn, and P. Koundouri (2003), 'Valuing the future : recent advances in social discounting', World Economics 4: 121–141; (2) Weitzman,M.L. (1998), 'Whythe far-distant future should be discounted at its lowest possible rate', Journal of Environmental Economics and Management 36: 201–208 and (3) Gollier, C. (2002), 'Discounting an uncertain future', Journal of Public Economics 85:149–166.

solving for interest rate, approximately the two per cent was obtained. Accordingly, two per cent discount rate was used in compounding as well as in amortizing variable cost of groundwater. This rate of 2 percent also realistically reflected the increase in the investment on borewells over time.

Relative influence of discount rate and bulky investments in borewell irrigation

The relative influence of discount rate, the bulky frequent investment by farmers on drilling and casing and the bulky infrequent investments by farmers on irrigation pumpset and related infrastructure is crucial to analyze. Given the decreasing (increasing) probability of well success (failure), and the decreasing life and age of irrigation wells, the amortized investment will be modestly sensitive to choice of discount rate. However, the cost of irrigation will largely be influenced by the frequent investments made by farmers on drilling and casing since irrigation pumpsets serve at least around 10 years and as they can be moved to another functioning borewell relatively easily and hence do not farm part of the sunk cost.

Amortized Cost of irrigation

Amortized cost of irrigation = (amortized cost of bore well + amortized cost of pump set + amortized cost of conveyance + amortized cost of over ground structure + annual repairs and maintenance costs of pump set and accessories)

Amortized cost of borewell

Amortized cost of BW = (compounded cost of BW) X $[(1+i)^{AL}$ X $i / (1+i)^{AL} – 1)]$

Where AL = average age or life of bore well, i = discount rate considered = 2 %.

Compounding investment on borewells

Farmers invest on irrigation well/s during different time periods, and their wells have different vintages. In order to bring all historical costs / investments on borewells on par, investments made by different farmers in different years, are compounded to the present (say 2018) at the interest rate of two percent.

Compounded cost of BW = (historical investment on BW) * $(1+i)^{(2018\text{-year of drilling})}$ if 2018 is considered as the reference year

Amortized cost of Pump set (P) and Accessories (A)

Amortized cost of P and A = (compounded cost of P and A) * $[(1+i)^{12}$ * $i / (1+i)^{12} – 1]$

(The working life of pump sets and accessories (P and A) is considered to be 12 years as reflected by field data.)

Compounded cost of P and A = (historical cost of P and A) * $(1+i)^{(\text{say 2018 – year of installation of P and A})}$

Amortized cost of conveyance structure

Amortized cost of conveyance structure (CS) =(compounded cost of CS)*$[(1+i)^{12}$ *$i/(1+i)^{12} – 1]$

The working life of conveyance structures (CS) is also considered to be 12 years.

The usual mode of conveyance of groundwater is through PVC pipe and the Compounded cost of CS = (historical cost of CS) * $(1+i)^{(2018 \text{ – year of installation of CS})}$

The study was conducted in the two most dry agro climatic regions of Karnataka which have the greatest exposure to market forces, namely the Eastern Dry Zone (Kolar district) and the Central Dry Zone (Chitradurga district). Kolar and Chitradurga districts are characterized as the two groundwater demanding horticulturally dominant districts of Southern Karnataka. A sample of 30 farmers having borewell(s) with drip irrigation for narrow spaced crops in Kolar District, 30 farmers having borewell(s) with drip irrigation for broad spaced crops in Chitradurga district, 30 farmers who are sharing their well water with their relatives / siblings in Chitradurga district and 30 farmers who have recharged their borewell(s) in Chitradurga district was chosen for detailed field work.

Variable and fixed cost of groundwater – How farmers are net subsidizing crops to consumers

Groundwater cost has fixed and variable cost components. Cost of groundwater varies from Rs. 200 per ha cm to Rs. 500 per ha cm in different agro-climatic zones, excluding the cost of electricity used for pumping, non-measurable due to lack of electricity metering (Tables 1,2)

Table 1: Variable cost (VC) and fixed cost(FC) and Total Cost (TC) of groundwater irrigation and Gross Returns (GR) and Net Returns (NR) for seasonal crops in Karnataka (Rs. Per acre)

Crop	Water used in ha cms	VC of groundwater	FC of groundwater	TC of groundwater	TC of cultivation	% TC of groundwater to TC of cultivation	Output	GR	NR including irrigation cost	NR excluding irrigation cost	NR per rupee of groundwater	Crop per drop = output per ha cm
Knol kohl (qtl)	12.08	22324	3776	26100	71822	36	155	90666	18844	44944	0.72	12.83
Coriander*	4.7	11765	7328	19093	59334	32	150	75000	15666	34759	0.82	31.91
Capsicum (qtl)	8.18	17583	6067	23650	153216	15	50	180000	26784	50434	1.13	6.11
Carrot (qtl)	7.59	17349	2120	19469	77528	25	109	108571	31043	50512	1.59	14.36
Beans (qtl)	10.31	25944	4251	30195	127881	24	70	182500	54619	84814	1.81	9.22
Red onion (qtl)	9.32	19034	5625	24659	80962	30	96	136693	55731	80390	2.26	10.30
Cabbage (qtl)	10.05	24045	2304	26349	154253	17	230	230476	76223	102572	2.89	22.89
Tomato (qtl)	12.16	20840	2107	22947	166490	14	110	238689	72199	95146	3.15	9.05
Potato (qtl)	11.92	25778	762	26540	121032	22	227	211012	89980	116520	3.39	19.04
Cauliflower (hds)	8.54	7321	2308	9629	74089	13	14545	118182	44093	53722	4.58	1703.16

Note: VC: variable cost of groundwater, FC: Fixed cost of groundwater, TC : Total cost , NR: Net returns, GR: Gross returns; *(in 100 bunches); qtl: quintals

Source: Kiran Kumar R Patil and MG Chandrakanth, Crop water planning and irrigation efficiency in Rainfed Agriculture, in Special Publication of the Geological Society of India, No. 5, 2016, pp. 36-46. (http://www.toenre.com/downloads/2016-kiran-mgc-crop-water-planning-GSI-article.pdf)

Table 2: Variable cost and fixed cost of groundwater irrigation of perennial crops in Karnataka (Rs. Per acre)

Crop	Water used in ha cms	VC of groundwater	FC of groundwater	TC of groundwater	TC of cultivation	% TC of groundwater to TC of cultivation	Output	GR	NR including irrigation cost	NR excluding irrigation cost	NR per rupee of groundwater	Crop per drop = output per ha cm
Coconut in nos.	8	6876	393	7269	33216	22	4635	36502	3286	10555	0.45	579.4
Banana (qtl)	32	18293	271	18564	95312	19	41	114531	19219	37784	1.04	1.3
Papaya (qtl)	14	21107	2494	23601	141649	17	193	233500	91851	115452	3.89	13.8
Arecanut (qtl)	12	8553	409	8962	62743	14	9	114824	52080	61043	5.81	0.8
Pomegranate (qtl)	10	17250	514	17764	169025	11	39	340540	171515	189279	9.66	3.9

Note: VC: variable cost of groundwater, FC: Fixed cost of groundwater, TC : Total cost , NR: Net returns, GR: Gross returns; qtl: quintals

Source: Kiran Kumar R Patil and MG Chandrakanth, op.cit

Table 3: Economics of groundwater irrigation in Karnataka

Particulars	Drip farms connected to narrow spaced crops, Kolar (n=30)	Drip farm connected to broad spaced crops, Chitradurga (n=30)	Shared well farms, Chitradurga (n=30)	Borewell Recharge farms, Chitradurga (n=30)
Average size of land holding (irrigated land area) (acres)	9.38 (4.61)	7.87 (6.07)	8.17 (4.77)	15 (9.89)
Gross irrigated area per farm (acre)	6.62 (1-26)	12.2 (2.4-43.4)	7.93 (0.75-21)	17.03 (4-47)
Net irrigated area per farm (acre)	3.01	6.44	3.40	8.08
Irrigation intensity (%)	220	189	233	210
Groundwater extracted per farm (ha cms per year)	72.94 (11-261)	69.21 (15.58-267)	88.75 (16 -238)	140 (26.18-397)
Groundwater extracted per functioning well (ha cms in 2012-13)	53.37 (11-86)	32 (11-77)	71.96 (9.28-127)	56 (8.72-150)
Amortized cost of drilling and casing + O and M costs per farm	152376	67303	17732	35182
Amortized investment on over-head storage structure, drip irrigation structure, artificial recharge structure, pump and motor, electricity charges and conveyance structure per farm	63115	29654	14144	46898
Variable cost of groundwater (Rs per ha cm)	2089 (71%)(295-9255)	972 (69%)(68-9517)	199 (56%)(18.59-1874)	251 (43%) (43-1127)
Fixed cost of groundwater (Rs per ha cm)	865 (29%)(317-3791)	428 (31%)(156-2046)	159 (44%)(39-875)	335 (57%) (97-1564)
Net returns per ha cm of groundwater (Rs) Range	7610 (784-22603)	7398 (1470-37554)	3888 (1277-16418)	3674 (1859-14533)
Net returns per acre of gross irrigated area (Rs) Range	83786 (6980-247046)	75463 (11420-168283)	43506 (15786-355787)	43457 (20810-80536)
Net returns per functioning well (Rs) Range	406158	227609 (59018-673135)	279795 (34432-896356)	288789 (31045-561485)
Net returns per rupee of irrigation cost (Rs) Range	2.57 (0.08-15.75)	5.08 (1.74-28)	10.83 (1.6-61.88)	8.17 (1.32-18.29)
Negative Binomial Probability of well success	0.32	0.28	0.68	0.27

Note : Figures in the parenthesis indicate range

Source: Kiran Kumar R Patil and MG Chandrakanth, op.cit

It can be observed that the cost of groundwater formed around 15% of the cost of cultivation of perennial crops, and 30 % of the cost of cultivation of seasonal crops. This cost is totally borne by farmers implicitly. About 50 % to 70% of this cost is that of investment on groundwater wells and the rest is the electricity cost which is subsidized. Farmers are continuously incurring the variable cost of drilling wells. The free electricity cost forms around 25 percent of the cost of groundwater and the rest (about 70 to 755%) is borne by farmers due to frequent well failures.

It is crucial to recognize that the methodology of costing groundwater adopted by the CACP to fix the MSP, does not incorporate cost of groundwater as cost of well failures is ignored and treated similar to depreciation assuming that wells serve for around 10 years at least. Thus, the cost of irrigation water largely varies life, age, and number of well failures and serving wells. Accordingly, areas (farmers) irrigated by groundwater which form fifty percent of the total area irrigated in Karnataka (and 70% of the area irrigated in India) are net subsidizing the cost of groundwater irrigated crops due to increasing probability of failure of irrigation borewells and non accountability of negative externality leading to frequent well failures.

Economics of groundwater irrigation

The choice of micro irrigation technology is lead by scarcity of groundwater and scarcity of labour. Cost of groundwater in drip irrigation farms increases due to shifting to drip system after considerable initial / premature failure of wells. The NBD probability of well success varied from 0.27 to 0.68 (Table 3).

Policy implications

This study demonstrates the application of the theory of externalities in costing groundwater for irrigation with the following implications.

1. Cost of groundwater forms around 15 percent and 30 percent of the cost of cultivation of perennial and seasonal crops respectively, implicitly borne by farmers and net subsidizing consumers.
2. Currently variable costs of drilling and casing forms around 50 to 75 percent of the investment on borewells. Energy cost forms around 25 percent of the cost of groundwater. Energy subsidy is often highlighted as a windfall support to farmers though farmers are bearing major portion of cost, subsidizing the crops to the society.
3. Estimation methodology of cost of cultivation by Commission for Agricultural Costs and Prices (GoI) does not include variable cost of groundwater and grossly underestimates the cost of cultivation of groundwater crops. The CACP accordingly may modify its methodology incorporating the variable costs of groundwater irrigation reflecting *inter alia* costs of drilling and casing, probability of well failure
4. Choice of right crops, pumping right volume of water, using micro irrigation, water budgeting, focusing not on more crop per drop, but on the strategy of net returns per rupee of the cost of water are crucial.
5. Irrigation extension, a separate wing or emphasis by Department of agriculture / horticulture, needs to be established involving agricultural engineering and agricultural / horticultural graduates educating farmers and consumers to treat water with wisdom, respect and equity for sustainable use.
6. Devising and installing low cost water measuring devices, promoting low water high value crops – flowers, fruits, vegetables is crucial.
7. Cultivation of climate smart crops such as millets harvestable in 70 to 80 days, saves duration, improves food, health and nutrition security for both humans and livestock.

References

1. MG Chandrakanth, Water Resource Economics - Towards a Sustainable Use of Water for Irrigation in India, Springer, New York, 2015.
2. Kiran Kumar R Patil and MG Chandrakanth, Crop water planning and irrigation efficiency in Rainfed Agriculture, in Special Publication of the Geological Society of India, No. 5, 2016, pp. 36-46.
3. MG Chandrakanth and Kiran Kumar R Patil, Internalization of externalities and costing groundwater for irrigation: Evidence from a micro study in Karnataka, Arthika Charche, FPI Journal of Economics and Governance, Vol 3, No.2, 2018, pp. 29-40.

Institute for Social and Economic Change

Dr. V K R V Rao Road, Nagarabhavi PO, Bangalore 560072

Phone: 23215468, 23215519, Fax: +91-80-23217008; Web: http://www.isec.ac.in