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Contents

Internalization of Externalities and Costing Groundwater for Irrigation: Evidence from a Micro Study in Karnataka

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Abstract

About 70 percent of irrigation water and 85 percent of drinking water of India is dependent on groundwater. The focus of groundwater development has always been on 'demand side', i.e. enhanced pumping, and relegating 'supply side' of groundwater recharge. This study demonstrates that reciprocal negative externality due to cumulative interference of wells may add at least 15 to 30 percent of the cost of cultivation of crops, which is currently borne by farmers. Farmers are thus net subsidizing groundwater crops, while policy makers claim provision of free electricity for pumping - a small component of cost of cultivation. It is crucial for the Commission for Agricultural Costs and Prices to upgrade the cost of cultivation methodology by incorporating negative externality. Provision of low cost water measuring device educates farmers towards sustainable use of cultivating high value - low water crops.

1. Introduction

In Karnataka, there are around 25 lakh irrigation wells with more than 70 percent of them being Borewells. The figures are debatable as they differ with source and there are no records of borewells. For instance, Karnataka Power Transmission Corporation Limited (KPTCL) has a record of irrigation pumpsets electrified but no information on failure of wells or failed wells. Perhaps, farmers do not report their well failure because obtaining electricity connection for wells is an onerous task.

In groundwater use, the draft (how much water is pumped out) and recharge (how much water is sent back to aquifer) are estimates, and vary by methodology used. The probability of well success is usually measured using the Negative Binomial Distribution. The estimated negative binomial probability of success of borewell at 0.3, implies a high rate of initial and premature failure of borewells. Around three lakh dug wells / open wells in the state have already dried up.

Currently, more than 85 percent of water is utilized by agriculture by way of irrigation in India. Water use for irrigation is referred to as 'consumptive use', which implies that once water is applied to crops, it cannot be recovered. In contrast, water use for domestic/ industrial purposes is referred to as 'non-consumptive use', where water is recoverable, such as sewage water and waste water. About 70 percent of irrigation is met by groundwater and 30 percent is met by surface water from rivers, dams, canals, tanks. Hard rock areas of India constitute 65 percent of India's geographical area where recharge is less than 5 to 10 percent of rainfall. Hard rock areas constitute India's highest demand for groundwater resource.

At present, water policies are heavily focused on the demand side of groundwater (extraction) intervention rather than supply side of (recharge) intervention. If development implies 'welfare', in the case of 'groundwater development' it means

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'groundwater extraction'. Thus, the demand side is getting all the focus rather than the supply side. Users of groundwater are myopic as they do not appreciate that groundwater in hard rock areas is largely a function of recharge.

Due to groundwater illiteracy among all users including farmers who are the largest users of the resource, farmers treat expenses relating to groundwater as an implicit cost. One of the major reasons for this is that groundwater wells used to serve at least for more than 15 to 20 years earlier. The life and age of groundwater wells is falling drastically due to over extraction as well as negative externalities as a result of cumulative interference among irrigation wells.

However, farmers pumping groundwater are unaware of how their investment in irrigation wells and water should be accounted to the cost of cultivation of crops, so that they recover the cost from the returns. In addition, research literature concerning with the economics of irrigation, seldom considers water as an input or resource in production process. While frequency of irrigation and labor for irrigation is taken as irrigation cost, groundwater is considered as a free or costless input. This idea was also triggered by the fact that, since 1982, electricity used to pump groundwater has been virtually supplied free of cost.

Historically, the groundwater usage has undergone many distinct periods. During 1950 – 1965, which can be referred to as pre-green revolution period, the surface water through tanks and canals were the major sources of irrigation. The Green Revolution period (1965-1980), had schemes, such as, million wells scheme and thousand wells scheme, which had promoted rapid exploitation of groundwater. Thus, Green Revolution can also be referred to as Groundwater Over exploitation revolution. The shallow dug wells, attached with manual lifts - Yetha, Kapile, Picota and Persian wheel (bucket machine) - for extracting water supported subsistence irrigation.

During 1980 – 1990, dug-cum-borewells were in operation using an average of 5 HP centrifugal pumps lifting water, and wells were drilled deeper – to cultivate exploitative crop pattern like paddy and vegetables. In this period, well failure began surfacing. The period 1990 – 2000 witnessed shallow borewells with submersible pumpsets of 5 to 10 HP capacity supporting paddy, maize, sugarcane, vegetables. The rate of well failure further increased and groundwater was still applied through flow irrigation as economic scarcity of groundwater was not perceptible. Since 2000, use of deep borewells with submersible pumpsets using more than 10 HP capacities, but usually hidden as around or below 10 HP (because pumps above 10 HP attract payment of electricity charges), were witnessed. However, the groundwater pumped slowly began to be applied through micro irrigation. The rate of well failure was around 70 percent in many parts of dry agro climatic zones. The initial failure and premature failure of borewells began to surface due to unsustainable extraction of water for irrigation.

This article focuses on costing groundwater for irrigation in Karnataka State by emphasizing both supply and demand side factors. Supply-side is demonstrated by farmers ability to reap economic and hydrogeological benefits of on-farm groundwater recharge while sharing their well water with their siblings. In addition, groundwater recharge technologies and benefits of sharing well water, and comparisons with parallel demand side technological efforts of using drip irrigation are analysed. The farmers who have neither adopted drip irrigation nor the supply side aspects are considered the 'control' group data.

2. Theoretical background

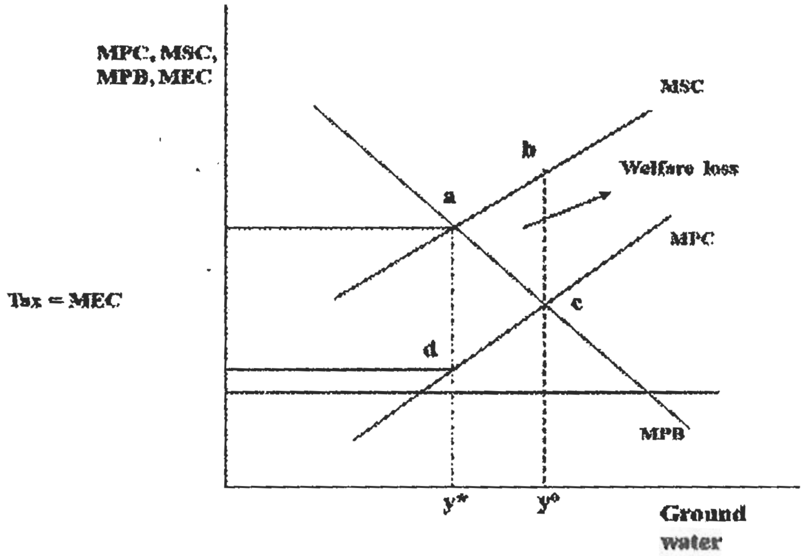
According to Baumol and Oates (1988), conditions for the presence of externality are characterized by this following: Action of one agent should result in an unintended side effect on another agent through production/consumption function of another agent and result in inefficiency and welfare loss which are not regulated by price mechanism or other institutions. The reciprocal externality propounded by Dasgupta (1982) indicates that one irrigation well drilling deeper or extracting higher volume of groundwater will influence the yield of other wells, but it is very difficult to locate or pin point well/s responsible for the influence.

In this study, both the above concepts are used in the empirical definition of externality. First, using the Baumol and Oates (1988) concept of externality, drilling of borewell/s by a farmer has unintended side effect of increasing the depth of drilling by neighboring farmer/s. This action of drilling affects the production function of the neighboring farmer, by raising the costs of irrigation. Due to this negative externality, extraction of groundwater increases and results in inefficiency and welfare loss. The phenomenon has no place for offering compensation to farmer/s suffering due to increasing cost of irrigation due to a well failure. In addition, there are no institutions regulating drilling irrigation wells and even if they exist, their governance is weak. This is also a case for negative reciprocal externality since it is extremely difficult to locate the farmer/s responsible for increasing the cost of extraction of groundwater as all farmers are cumulatively involved in extraction by drilling, and are cumulatively responsible for increasing the cost of irrigation. As the largest pumper of groundwater in the world with the largest number of irrigation wells (exceeding 25 million), India may first need to estimate the negative externality convincing the stakeholders and face tough reaction with farmers' facing not so favorable balance of trade. Thus a pigovian tax is a theoretical notion for India.

The above concept of externality corroborates for hard rock areas of India fraught with cumulative interference of irrigation wells due to cone of depression created by every additional well. Further, there has been no effort on the part of either Agriculture department / Horticulture Department / Minor Irrigation / Department of Mines and Geology including the Central Groundwater Board, towards creating awareness among farmers, borewell dig owners and other stake holders regarding the nature of groundwater recharge, extraction and flow, since in their semantics, groundwater development means only groundwater extraction and discounts recharge. 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. Over-extraction of groundwater has resulted in increasing probability of initial /premature failure/s of irrigation well/s, along with reduced yield of water and reduced area irrigated on other farmers' field.

Following is an explanation of this situation. Farmers by violating isolation distance between wells, impose externality on neighbouring farmer/s. Now, the cost of extraction of groundwater is equal to Marginal cost of extraction (MC) + Opportunity cost incurred by neighbouring farmer/s due to over extraction by the farmer. Or, a farmer imposes a social cost on neighboring farmer/s forcing neighbour to drill deeper, or use higher capacity pump or forced to drill additional well. Figure 1 shows the measurement of this externality by Marginal Externality Cost given by the difference between Marginal Social Cost (MSC) and Marginal Private Cost (MPC). As a farmer is not bearing this MEC, he is extracting yo, which is determined by the point where his Marginal Private Benefit (MPB) equals MPC. However, farmer should have extracted only y* which is the socially optimal value where MPB = MSC. Thus, farmers (and the society) ignore this negative externality which is a social cost. This results in inefficiency given by over extraction ((yo - y*)>0) and welfare loss (triangle abc).

Figure 1: Negative externality leading to overextraction of groundwater



Source: Chandrakanth, 2015

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

The extent of internalization of externality depends upon each farmer. Farmers who adopt micro irrigation technologies, for instance, are internalizing demand side of groundwater. Farmers who have undertaken on farm groundwater recharge are internalizing the supply side of groundwater. Similarly, farmers who adopt low water, high value crops are internalizing the demand side of groundwater. And so are farmers who are sharing their well water with relatives / siblings and others who are involved in water markets.

3. Empirical approaches to costing groundwater for irrigation

During the green revolution period, the dug wells and dug cum borewells were the dominant sources of water extraction structures. As the wells were sparse and were using the traditional lifts such as yetha, kapile, picota, Persian wheel, and as the farmers were also cultivating crops which were not so water intensive, the productive life of irrigation wells was around 25 to 50 years. As the traditional lifts were manual/driven by bullocks and as the wells served for a fairly long period of time, the depreciation on wells was the fixed cost of groundwater irrigation. In class rooms of Agricultural Universities, the (variable) cost of irrigation was taught as the labor cost involved in irrigation. Irrigation was also measured in terms of frequency per week or per month, the volume was not given due consideration, as the frequency does not depend upon the area irrigated. Thus, as groundwater did not show symptoms of resource scarcity, the cost was modest and subsumed in depreciation. However, by the end of green revolution and in post green revolution, due to (a) violation of isolation distance between irrigation wells (prescribed as 650 feet between open wells or dug wells and 850 feet between borewells), (b) change in cropping pattern towards water intensive crops such as paddy, sugarcane, vegetables, fruits and other horticulture crops, (c) arrival of fast rigs, and (d) advent of shallow and deep borewells, on the one hand the life of irrigation wells began reducing drastically from 25 years to below 10 years. In addition, the yield of the well (volume of groundwater pumped per hour) reduced. Over time, due to secular overdraft of groundwater and the cone of depression and cumulative interference among irrigation wells, the probability of well success as well as the life of irrigation wells declined.

Since 2000, life of irrigation wells has fallen drastically to less than five years, forcing farmers to drill additional well/s. Thus, depreciation which was representing the fixed cost of irrigation earlier when the well life was at least above ten years, becomes a smaller component of the total cost of irrigation. Consequantly, variable cost component of irrigation represented by drilling additional well/s due to initial failure or premature failure of wells, becomes a dominant part of the total cost. Empirically, this situation calls for analysis on increasing variable cost of groundwater irrigation due to (a) falling life of irrigation wells and (b) increasing initial and premature well failure. As the life of irrigation well falls, the variable cost of drilling and casing of irrigation wells need to be amortized over the short life at a discount rate.

Methodology by the Commission for Agricultural Costs and Prices (CACP) considers depreciation on (functioning) irrigation well and irrigation pump (IP) for non-specified number of years. If probability of a borewell failure is high, investment on irrigation borewells may not be considered as a fixed cost, as the farmers are forced to invest on additional well/s till they strike groundwater. This involves frequent if not recurrent investment on drilling and casing.

The CACP methodology has poor basis for computation of depreciation because it considers only investment on functioning / working wells and ignores huge investments made on failed wells by farmers, and if schedule does not have any information sought from farmers regarding well failure and the associated investments. Thus, the methodology is devoid of incorporating the rise in cost of groundwater due to increasing well failure. The cost of groundwater is considered only as a depreciation on borewell with no mention of number of years of well life. In reality, the water volume pumped fluctuates due to interactive effects of wells influenced by the cone of depression which, in turn, influences the probability of well failure. That part of investment on wells (such as drilling, casing) needs to be treated as a variable cost and the part of the investment on irrigation pumpset, pump house, pipes and accessories needs to be treated as fixed cost. The challenge is to find the years of well life for calculation of variable cost. However, CACP bases the MSP (Minimum Support Price) of crops, using the cost of cultivation data collected from farmers, grossly discounts the cost of groundwater as the cost of well failure is not incorporated. Consequently, the cost of cultivation of groundwater irrigated crops is underestimated by the CACP[3].

4. Need for a new approach to costing groundwater resource

Groundwater resource is extracted / pumped by the farmers, and electricity to pump the water is free. Nevertheless, farmers incur more than 70 percent of cost of groundwater themselves and are net subsidizing consumers instead of receiving subsidies. With 65 percent of geographical area of India being hard rock area with poor recharge (of 5-10 percent of rainfall), where groundwater irrigation dominates, it is crucial to properly account for cost of groundwater resource.

Reciprocal negative externality is the key for above costing and needs knowledge on

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[3] This underestimation is indicated long before. For instance, way back in 1994, Professor MV Nadkarni, indicated that the cost of irrigation water from irrigation wells should include both the investment made on functioning wells and on failed wells, due to the presence of externality. By ignoring the cost or investment made on failed wells, he argued that the cost of irrigation would grossly underestimated. http://www.toenre.com/ford-website/index1.htm

different types of wells and costs considered. In particular, 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)[4]; (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).

4.1 Measurement of Reciprocal Externality and costing groundwater resource

The existence of externality in hard rock areas, is indicated by the presence of well failure. If a farmer does not have any failed well, s/he has not suffered externality. Or, if a farmer has failed well/s, then this failure is due to negative externality caused by cumulative interference effects of irrigation wells. This externality per well is estimated by [(Amortized investment on drilling and casing of bore- wells over the subsistence/ economic life of well/s) ÷ [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/ economic life of well/s)] ÷ [Number of all types of wells on the farm].

If A denotes (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; and B denotes (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, and 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. The basis of the hypothesis is that all wells in hard rock areas succumb to cumulative interference among irrigation wells.

Methodology of costing groundwater by fixed and variable costs, calculation of groundwater use, annual cost of irrigation by (a) amortized cost of borewell with specification of life and age of borewells and discount rate, (b) compounding investments on borewells and (c) amortized cost of pumpset and accessories are technical and complex. They are sourced from Chandrakanth (2015) and applied for data in the empirical study as detailed below.

5. Data

The study is based on field data collected in the two most dry agro climatic regions of Karnataka for the agriculture year 2012-13 which have the greatest exposure to market forces, namely the Eastern Dry Zone (Kolar district) and the Central Dry Zone (Chitradurga district). These districts are characterized by groundwater demanding and 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.

Data collected includes the historical investments by sample farmers on irrigation

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[4] 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 annual net returns on the farm.

wells. In fact, the vintage of investment on irrigation well/s varies for every farmer inter alia with returns, repaying capacity, risk bearing ability, probability of well failure influenced by cumulative interference of irrigation wells.

6. Empirical Results

Basic results on costing groundwater by fixed and variable cost components by select crops are presented in Table 1 and Table 2. 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. Further, the results indicate that cost of groundwater varies from 13 percent of the cost of cultivation in cauliflower to 36 percent of the cost of cultivation in KnolKhol (Table 1). On the other hand, the cost of groundwater varies from 11 percent of the cost of cultivation in pomegranate to 22 percent of the cost of cultivation in coconut crops (Table 2). Thus, the cost of groundwater increases for seasonal crops and reduces for perennial crops due to time and scale involved. On an average, the cost of groundwater forms around 15 percent of the cost of cultivation of perennial crops, and 30 percent of the cost of cultivation of seasonal crops,and is borne by farmers implicitly. About 50 percent to 70 percent of this cost is that of investment on groundwater and the rest is the subsidized electricity cost. Thus, farmers are bearing the major portion of groundwater cost and accordingly are subsidizing the society. Further about 5000 liters of water are used to produce 1kg of paddy, and cost of irrigation for millets is 1/4th that of paddy. The procurement of millets can serve as incentive for farmers to cultivate and supply. Millets (fox tail, barn yard, little, kodo, proso millets) are climate smart crops, low water users and come to harvest in 70 to 90 days.

Table 1: Variable and fixed costs of groundwater irrigation of vegetable crops in Eastern dry agro climatic zone of Karnataka

(Rs. Per acre)

Crop	Water used in ha cms	VC of ground-water	FC of ground-water	TC of ground-water	TC of culti-vation	% TC of groundwater to TC of cultivation	Output	GR	NR including irrigation cost	NR excluding irrigation cost	NR per rupee of ground-water	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: Patil and Chandrakanth (2016)

Table 2: Variable and fixed costs of groundwater irrigation of perennial crops in Eastern dry agro climatic zone of Karnataka

(Rs. Per acre)

Crop	Water used in ha cms	VC of ground-water	FC of ground-water	TC of ground-water	TC of culti-vation	% TC of groundwater to TC of cultivation	Output	GR	NR including irrigation cost	NR excluding irrigation cost	NR per rupee of ground-water	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: Patil and Chandrakanth (2016)

7. Policy Issues and debates

The above basic results have useful implications for current policy issues and debates. These are analyzed below.

7.1 Is Electricity subsidy a windfall gain for farmers?

Government of Karnataka's subsidy towards free supply of electricity to 21.06 lakhs Irrigation Pumpsets below 10 hp, and 22.90 lakh Bhagya Jyothi / Kutir Jyothi households increased to Rs.5381 crores in 2013-14 from Rs.4722 crores in 2012-13. Bulk of this increase is due to increase in the use of electricity by irrigation pumpsets users from 15318 million KWHs to in 2012-13 to 16679 million KWHs in 2013-14. In the absence of electrical meters installed on these irrigation pumpsets, the estimated supply of electricity is taken as a residual after deducting all metered supplies. This residual forms around 34 percent of the total energy provided[5]. However, the residual also includes Transmission and Distribution losses in the distribution system and, in general, the estimated power supplied to agriculture / irrigation is over estimated.

In Karnataka and most other States in India, farmers using irrigation pumpsets (e.g. below 10 hp capacity) for groundwater are not charged for electrical power, and the quality of power supply is also not satisfactory. The State Government imposed a flat charge of Rs. 300 per hp per year for pumpsets upto 10 hp since April 1997. This charge is not strictly collected for the reasons of political economy. Over the years, the State Governments have preferred not to install energy meters for irrigation pumpsets. In addition, the transaction costs involved in obtaining the electrical meter reading reflecting energy use to pump groundwater are colossal because the irrigation borewells are spread throughout the State, which enhances both the fixed cost of installing meters as well as the cost of obtaining meter readings from meter readers. Thus, currently as well as historically, successive Governments preferred not to install electrical meter for each irrigation pumpset. In addition, there is stiff resistance from farmers for installation of electrical meters on irrigation pumpsets due to the apprehension that they would be billed for pumping groundwater for irrigation[6]. Obviously, there are no explicit payments towards electricity for pumping groundwater other than annual operation and maintenance charges of the irrigation pump set and borewell.

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[5] https://powermin.nic.in/sites/default/files/uploads/joint_initiative_of_govt_of_india_and_Karnataka.pdf

[6] For instance, farmers handed over around 200 electrical meters installed on their irrigation pumpsets to officials of BESCOM and demanded removal of over 700 meters installed in irrigation pumpsets fearing that they would be billed for pumping groundwater for irrigation. The Hindu, 10/1/2004

While farmers are not charged for electricity to pump groundwater for irrigation, there are no compelling reasons to believe that they are enjoying a windfall gain as they incur the variable cost of drilling wells on all types of borewells indicated above. It is estimated that the free electricity cost is around 25 percent of the cost of groundwater and the rest (about 75 percent) is borne by farmers.Methodology of costing followed by Directorate of Economics and Statistics, Commission for Agricultural Costs and Prices does not adequately account for cost of groundwater as already mentioned. Accordingly, areas (farmers) irrigated by groundwater which form fifty percent of the total area irrigated in Karnataka (and 70 percent of the area irrigated in India) are net subsidizing the cost of groundwater irrigated crops due to increasing probability of failure of irrigation borewells.

7.2 Why are farmers net subsidizers of groundwater irrigation?

The cost of irrigation water varies considerably with the number of well failures. For instance, farmers with 1 initial well failure formed 18 percent of the sample farmers and their cost of irrigation varied from Rs. 230 to Rs. 2824 per ha cm, while farmers with 2 initial well failures on the farm formed 11 percent of the sample, and their cost of irrigation varied from Rs. 430 to Rs. 4607 per ha cm. What is crucial is to note that 4 percent of farmers experienced even five initial failures. In case of conventional or flow irrigation the cost of groundwater varies also with the technology. of irrigation. In the case of conventional or flow irrigation, the cost per ha cm is lower than drip irrigation, as the denominator in conventional irrigation is higher than drip irrigation (Table 3).

Table 3: Range in the cost of groundwater depending upon the number of initial failures of irrigation wells

Number of initial failures of borewell per farm	% of sample farms	Range in cost per ha cm of groundwater (flow to drip irrigation)
0	57	177-2937
1	18	230-2824
2	11	430-4607
3	5	186-1834
4	5	696-3156
5 and above	4	290-4467

Source: Patil and Chandrakanth (2016)

In addition, the choice of drip irrigation technology is driven by scarcity of groundwater as well as scarcity of labour. Therefore, the cost of groundwater in drip irrigation farms increases due to farmers shifting to drip irrigation after facing considerable initial failure of irrigation wells as well as premature failures, which both increase the cost of irrigation. The shift to drip irrigation is relatively motivated by economic scarcity of groundwater in Central Dry Agro-climatic zone, while the shift to drip irrigation is relatively motivated by both economic scarcity of groundwater and labor on Eastern dry agro climatic zone. The experience of initial and premature failure of irrigation wells is measured using the Negative Binomial Distribution (NBD) probability of well success (number of wells to be drilled by farmer to obtain a successful well) from 0.27 to 0.68 (Table 4).[7]

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[7] The NBD probability of well success is influenced by mean and variance of obtaining successful well on the farm and years the well functions to yield water.

Table 4: 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 (10470-1325423)	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: Patil and Chandrakanth (2016)

7.3 Why 'more crop per drop' is not a right strategy?

Often, the agronomists and crop scientists strongly favour the strategy of 'more crop per drop' of water in order to maximize the returns of farmers. This strategy lacks crucial variable of cost of groundwater in estimation of cost of cultivation. In other words using the strategy of 'more crop per drop' can result in over production for non- incorporation of the scarcity value of the precious groundwater, which is rising over time due to focus on demand side in relation to supply side of groundwater. Thus, the farmers need to consider the net return per rupee of cost of irrigation water which incorporates the cost of groundwater resource. The net return per rupee cost of groundwater varied from Rs.2.57 in Eastern Dry agro climatic zone to Rs.10.83 in Central Dry agro climatic zone (14th row in Table 4).

8. Conclusion and implications

This study demonstrates the application of the theory of externalities in costing groundwater for irrigation. The hydrogeological aspects of interactive effects of wells due to cone of depression result in cumulative interference among irrigation wells causing negative reciprocal externalities. The key finding of this analysis is that, internalization of externalities due to cumulative interference adds around 15 percent to 30 percent of the cost of cultivation of crops, which is currently and implicitly borne by farmers. Thus, groundwater farmers are net subsidizing the groundwater irrigated crops. Given that fifty percent of the area irrigated in Karnataka is by groundwater irrigation, and around 70 percent of irrigation in India is by groundwater, the extent of subsidization by farmers to society could be substantial. The extent of this subsidization is about 15 percent to 30 percent of the cost of cultivation depending upon perennial crops or seasonal vegetable crops respectively.

Currently, the estimation of cost of cultivation by the CACP does not include the variable cost of groundwater and hence, grossly underestimates the cost of cultivation of groundwater crops. Hence, it is necessary for CACP to modify its methodology by incorporating the variable costs of groundwater irrigation reflecting *inter alia* the costs of drilling and casing, the probability of well failure. This is also usefull to incorporating the cost of negative externality in groundwater irrigation.

Further, it is crucial to create awareness among farmers regarding the prudent and frugal usage of groundwater by the choice of high value and low water intensive crops through micro irrigation to addressing the demand side of groundwater. In addition, efforts towards on farm groundwater recharge is important to addressing the supply side of groundwater. Currently, the investment on drilling and casing forms around 50 percent of the investment on borewells depending upon the hard rock, previous drilling attempts, probability of well success, life of irrigation wells and recharge efforts. The energy cost forms around 25 percent of the cost of groundwater. This energy subsidy is often highlighted as a windfall support to farmers, though it forms a modest proportion of the cost of groundwater. However, it is the groundwater farmers who are bearing the major portion of groundwater cost and accordingly are subsidizing the crops to the society and not vice versa. The electricity supplied is treated as a residual for lack of electrical meters installed on farmers' wells. This residual is only an estimate and often includes T and D losses too.

Apart from the choice of right crops, pumping right volume of water, using the technology of micro irrigation, sound 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. Irrigation extension, a separate wing or emphasis by Department of agriculture / horticulture, needs to be established involving agricultural engineering and agricultural / horticultural graduates.

On each borewell, low cost water measuring devices need to be installed for the farmer to be aware of volume of water pumped every day for every crop and every fragment of land. Avoiding cultivation of water intensive crops such as paddy, sugarcane and maize and promotion of low water and high value crops such as flowers, fruits, vegetables is crucial. Cultivation of climate smart crops such as millets which are low water users and low duration crops harvestable in 70 to 80 days, saves duration, improves health and nutrition security for both humans and livestock, and facilitate in sustainable use of the resource. Ultimately, farmers and users of groundwater need to be educated to treat water with wisdom, respect and equity.

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