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 pumps of 5 to 10 HP capacity for paddy, maize, sugarcane, vegetables. Rate of well failure increased. Post 2000, witnessed deep borewells with pumps of more than 10 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)\(^2\), 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)\(^6\) 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. 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 \(y\), 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 = \(y^* - y\) 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.

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

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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.

**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 occurring well failures. This way they are not 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)); (3) Wells with premature failure (borewell/s which served below subsistence life or the PBP); and (4) Wells with economic life (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 = \( (\text{Amortized investment on drilling and casing of bore-wells over the subsistence life of well/s or economic life of well/s whichever is relevant}) - \text{[number of wells which served PBP + number of wells serving economic life]}) \times \text{Amortized investment on drilling and casing of bore-wells over the subsistence life of well/s or economic life of well/s whichever is relevant}) \div \text{[Number of all types of wells on the farm]}.\)

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. 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.

**Variable cost of groundwater**

The variable cost of groundwater irrigation includes, amortizing the investment on drilling and casing of borewells 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 are-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 of life of borewell = \((0 + 4 + 4 + 4 = 10)/4 = 2.5\) years. The Average age or life was considered because, amortization of investment with time = \(0\), 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". 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. Further they indicate that the rate of growth of nominal investment in irrigation wells in different parts of Karnataka was \(i = 2\) 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) = ILW. Upon

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5 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.


6 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. Further they indicate that the rate of growth of nominal investment in irrigation wells in different parts of Karnataka was \(i = 2\) 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) = ILW. Upon
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 their wells have different vintages. In order to bring all historical costs / investments on borewells on par, investments made by different farmers in their wells have different vintages. In order to bring all historical costs / investments on borewells on par, investments made by different farmers in their wells have different vintages.

Compounded cost of BW = (historical investment on BW) * (1+i) (2018-year of drilling) if 2018 is considered as the reference year.

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)

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water used in ha</th>
<th>VC of groundwater</th>
<th>FC of groundwater</th>
<th>TC of groundwater</th>
<th>TC of cultivation</th>
<th>% TC of groundwater to TC of cultivation</th>
<th>Output</th>
<th>GR</th>
<th>NR including irrigation cost</th>
<th>NR excluding irrigation cost</th>
<th>NR per hectare of groundwater</th>
<th>Crop per drop of output per ha cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Knol kohl (qtl)</td>
<td>12.08</td>
<td>22324</td>
<td>3776</td>
<td>26100</td>
<td>71822</td>
<td>36</td>
<td>155</td>
<td>19066</td>
<td>18844</td>
<td>44944</td>
<td>0.72</td>
<td>12.83</td>
</tr>
<tr>
<td>Coriander*</td>
<td>4.7</td>
<td>11765</td>
<td>7328</td>
<td>19093</td>
<td>59334</td>
<td>32</td>
<td>150</td>
<td>75000</td>
<td>55666</td>
<td>34759</td>
<td>0.82</td>
<td>31.91</td>
</tr>
<tr>
<td>Capsicum (qtl)</td>
<td>8.18</td>
<td>17583</td>
<td>6067</td>
<td>23650</td>
<td>153216</td>
<td>15</td>
<td>50</td>
<td>180000</td>
<td>26784</td>
<td>50434</td>
<td>1.13</td>
<td>6.11</td>
</tr>
<tr>
<td>Carrot (qtl)</td>
<td>7.53</td>
<td>17349</td>
<td>2120</td>
<td>19469</td>
<td>77528</td>
<td>25</td>
<td>109</td>
<td>108571</td>
<td>31043</td>
<td>50512</td>
<td>1.59</td>
<td>14.36</td>
</tr>
<tr>
<td>Beans (qtl)</td>
<td>10.31</td>
<td>25944</td>
<td>4251</td>
<td>30195</td>
<td>127881</td>
<td>24</td>
<td>70</td>
<td>182500</td>
<td>54619</td>
<td>84814</td>
<td>1.81</td>
<td>9.22</td>
</tr>
<tr>
<td>Red onion (qtl)</td>
<td>9.32</td>
<td>19034</td>
<td>5625</td>
<td>24659</td>
<td>80962</td>
<td>30</td>
<td>96</td>
<td>136963</td>
<td>55731</td>
<td>80390</td>
<td>2.26</td>
<td>10.30</td>
</tr>
<tr>
<td>Cabbage (qtl)</td>
<td>10.05</td>
<td>24045</td>
<td>2304</td>
<td>26349</td>
<td>154253</td>
<td>17</td>
<td>230</td>
<td>230476</td>
<td>76223</td>
<td>102572</td>
<td>2.89</td>
<td>22.89</td>
</tr>
<tr>
<td>Tomato (qtl)</td>
<td>12.16</td>
<td>21840</td>
<td>2107</td>
<td>22947</td>
<td>166490</td>
<td>14</td>
<td>110</td>
<td>238689</td>
<td>72199</td>
<td>95146</td>
<td>3.15</td>
<td>9.05</td>
</tr>
<tr>
<td>Potato (qtl)</td>
<td>11.82</td>
<td>25778</td>
<td>762</td>
<td>26540</td>
<td>121032</td>
<td>22</td>
<td>227</td>
<td>211012</td>
<td>89980</td>
<td>116520</td>
<td>3.39</td>
<td>19.04</td>
</tr>
<tr>
<td>Cauliflower (hds)</td>
<td>8.54</td>
<td>7321</td>
<td>2308</td>
<td>9629</td>
<td>74098</td>
<td>13</td>
<td>14545</td>
<td>116182</td>
<td>44093</td>
<td>53722</td>
<td>4.58</td>
<td>1703.16</td>
</tr>
</tbody>
</table>

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


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

<table>
<thead>
<tr>
<th>Crop</th>
<th>Water used in ha</th>
<th>VC of groundwater</th>
<th>FC of groundwater</th>
<th>TC of groundwater</th>
<th>TC of cultivation</th>
<th>% TC of groundwater to TC of cultivation</th>
<th>Output</th>
<th>GR</th>
<th>NR including irrigation cost</th>
<th>NR excluding irrigation cost</th>
<th>NR per hectare of groundwater</th>
<th>Crop per drop of output per ha cm</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coconut in nos.</td>
<td>8</td>
<td>6876</td>
<td>393</td>
<td>7269</td>
<td>33216</td>
<td>22</td>
<td>4635</td>
<td>36502</td>
<td>3286</td>
<td>10555</td>
<td>0.45</td>
<td>57.94</td>
</tr>
<tr>
<td>Banana (qtl)</td>
<td>32</td>
<td>18293</td>
<td>271</td>
<td>18664</td>
<td>95312</td>
<td>19</td>
<td>41</td>
<td>114531</td>
<td>19219</td>
<td>37784</td>
<td>1.04</td>
<td>1.3</td>
</tr>
<tr>
<td>Papaya (qtl)</td>
<td>14</td>
<td>21107</td>
<td>2494</td>
<td>23601</td>
<td>141649</td>
<td>17</td>
<td>193</td>
<td>233500</td>
<td>91851</td>
<td>115452</td>
<td>3.89</td>
<td>13.8</td>
</tr>
<tr>
<td>Areca nut (qtl)</td>
<td>12</td>
<td>8553</td>
<td>409</td>
<td>8962</td>
<td>62743</td>
<td>14</td>
<td>9</td>
<td>114824</td>
<td>52080</td>
<td>61043</td>
<td>5.81</td>
<td>0.8</td>
</tr>
<tr>
<td>Pomegranate (qtl)</td>
<td>10</td>
<td>17250</td>
<td>514</td>
<td>17764</td>
<td>169025</td>
<td>11</td>
<td>39</td>
<td>340540</td>
<td>171515</td>
<td>189279</td>
<td>9.66</td>
<td>3.9</td>
</tr>
</tbody>
</table>

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

Source: Kiran Kumar R Patil and MG Chandrakanth, op.cit
Table 3: Economics of groundwater irrigation in Karnataka

<table>
<thead>
<tr>
<th>Particulars</th>
<th>Drip farms connected to narrow spaced crops, Kolar (n=30)</th>
<th>Drip farm connected to broad spaced crops, Chitradurga (n=30)</th>
<th>Shared well farms, Chitradurga (n=30)</th>
<th>Borewell Recharge farms, Chitradurga (n=30)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average size of land holding (irrigated land area) (acres)</td>
<td>9.38 (4.61)</td>
<td>7.87 (6.07)</td>
<td>8.17 (4.77)</td>
<td>15 (9.89)</td>
</tr>
<tr>
<td>Gross irrigated area per farm (acre)</td>
<td>6.62 (1.26)</td>
<td>12.2 (2.43-4.3)</td>
<td>7.93 (0.75-21)</td>
<td>17.03 (4.47)</td>
</tr>
<tr>
<td>Net irrigated area per farm (acre)</td>
<td>3.01</td>
<td>6.44</td>
<td>3.40</td>
<td>8.08</td>
</tr>
<tr>
<td>Irrigation intensity (%)</td>
<td>220</td>
<td>189</td>
<td>233</td>
<td>210</td>
</tr>
<tr>
<td>Groundwater extracted per farm (ha cms per year)</td>
<td>72.94 (11-261)</td>
<td>69.21 (15.58-267)</td>
<td>88.75 (16-238)</td>
<td>140 (26.18-397)</td>
</tr>
<tr>
<td>Groundwater extracted per functioning well (ha cms in 2012-13)</td>
<td>53.37 (11-86)</td>
<td>32 (11-77)</td>
<td>71.96 (9.28-127)</td>
<td>56 (8.72-150)</td>
</tr>
<tr>
<td>Amortized cost of drilling and casing + O and M costs per farm</td>
<td>152376</td>
<td>67303</td>
<td>17732</td>
<td>35182</td>
</tr>
<tr>
<td>Amortized investment on over-head storage structure, drip irrigation structure, artificial rechage structure, pump and motor, electricity charges and conveyance structure per farm</td>
<td>63115</td>
<td>29654</td>
<td>14144</td>
<td>40698</td>
</tr>
<tr>
<td>Variable cost of groundwater (Rs per ha cm)</td>
<td>2089 (71%-295-0255)</td>
<td>972 (69%-08-9517)</td>
<td>199 (56%)-18.59-1874)</td>
<td>251 (43%-43-1127)</td>
</tr>
<tr>
<td>Fixed cost of groundwater (Rs per ha cm)</td>
<td>865 (29%-017-3791)</td>
<td>428 (31%-156-2046)</td>
<td>159 (44%)-039-975</td>
<td>335 (57%-97-1564)</td>
</tr>
<tr>
<td>Net returns per ha cm of groundwater (Rs) Range</td>
<td>7610 (784-22803)</td>
<td>7398 (1470-37554)</td>
<td>3888 (1277-16418)</td>
<td>3674 (1859-15433)</td>
</tr>
<tr>
<td>Net returns per acre of gross irrigated area (Rs) Range</td>
<td>83796 (6980-247046)</td>
<td>75483 (11420-168263)</td>
<td>43506 (15786-355787)</td>
<td>43457 (20810-80536)</td>
</tr>
<tr>
<td>Net returns per functioning well (Rs) Range</td>
<td>406158</td>
<td>227609</td>
<td>279795 (24432-896356)</td>
<td>288789 (31045-561485)</td>
</tr>
<tr>
<td>Net returns per rupee of irrigation cost (Rs) Range</td>
<td>2.57 (0.08-15.75)</td>
<td>5.08 (1.74-28)</td>
<td>10.83 (1.6-61.88)</td>
<td>8.17 (1.32-18.29)</td>
</tr>
<tr>
<td>Negative Binomial Probability of well success</td>
<td>0.32</td>
<td>0.28</td>
<td>0.68</td>
<td>0.27</td>
</tr>
</tbody>
</table>

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 75%) 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 irrigation groundwater 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 considerble 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**


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