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Do Farmers Gain by More Crop Per Drop?

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ABSTRACT

Farmers are often advised to cultivate 'more crop per drop' of water. But does this fetch higher profits? Utilising field data from Karnataka, the paper analyses, which strategy benefits the most in crop choice. Economic analysis indicates that the strategy of 'more crop per drop' fetched lower net return than the strategy of maximizing net returns. The highest yielding crops using 'more crop per drop' were papaya (14.12 kgs per M^3 of water) followed by palak (13.5), cabbage (11.99), ash gourd (11.39),tomato (10.02). Similarly, the crops fetching maximum net returns per rupee of expenditure on water were marigold (Rs 1.89 per rupee of water cost) followed by mulberry (1.63), chrysanthemum (1.30), palak (1.21), papaya (1.10). The implications of the study are,Punjab-Haryana farmers by cultivating rice as monocropping using three times groundwater used by Karnataka farmers are realising net return of Rs..50,000 per acre (without accounting for cost of groundwater), while Karnataka farmers by using one-third of groundwater, by following drip irrigation are realising net returns of Rs.1.13 lakhs per acre (by accounting for cost of groundwater) which is twice that of Punjab – Haryana farmers.

Key words: More Crop Per Drop, fixed cost, variable cost of groundwater, borewell irrigation

JEL: Q15, Q28, Q29

I

PREAMBLE

Water is not only the elixir of life, but also elixir of agriculture. Given that groundwater irrigation supports 70 per cent of India's agriculture, sustainable use of groundwater is crucial and vital considering the ever-increasing users and uses. India also has the largest number of irrigation wells in the world (27 million) pumping two times the groundwater used for irrigation in the US, or six times the groundwater used for irrigation in Europe (Chandrakanth, 2015). Considering the percentage of villages with groundwater irrigation in India, 63 per cent of the villages have borewell irrigation. Among the different States, 92 per cent of villages in Punjab have borewell irrigation followed by Himachal Pradesh (83 per cent) Uttar Pradesh (82 per cent), Haryana (81 per cent), Bihar (69 per cent) have access to borewell irrigation. Among southern States, Karnataka ranks the highest with 60 per cent of its villages with borewell irrigation followed by Andhra Pradesh (44 per cent), Pondicherry (24 per cent), Tamil Nadu (14 per cent) and Kerala (7 per cent) Thus, the access to groundwater irrigation across villages in India amounting to 63 per cent of the villages in itself is an indicator of the extent of dependence on fragile resource and the extent of unsustainable use with

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Punjab ranking the first among the Northern States and Karnataka ranking the first among the Southern states (Anonymous, 2007).

The latest study by NASA highlights the groundwater depletion in Punjab, Haryana and Rajasthan as "Groundwater is disappearing fast from the world and India is among the worst hit, shows data from NASA's Gravity Recovery and Climate Experiment (GRACE) satellites. Among the world's largest groundwater basins, the Indus Basin aquifer of India and Pakistan, which is a source of fresh water for millions of people, is the second-most overstressed with no natural replenishment to offset usage, according to data from GRACE satellites (https://gpm.nasa.gov/education/videos/indias-disappearing-water). Therefore it is crucial to consider whether the advocacy to produce 'more crop per drop' (MCPD) is better than maximizing profit per rupee of water.

The objective of this paper is to analyse whether 'more crop per drop' strategy is better than the strategy of maximizing net returns in farming and to identify the corresponding crops in the eastern dry agro climatic zone of Karnataka, where groundwater is economically scarce.

II

SAMPLING

For this study, farmers were sampled considering their access to irrigation tank and the criteria of sharing water among relatives due to water scarcity on the farm. One of the unique features of this region is the popularity of drip irrigation due to economic scarcity of groundwater resource. Accordingly, the sampling frame included farmers located in the command area of irrigation tank receiving the benefit of recharge of irrigation tank characterised as with tank recharge (WTR); farmers who are not under the command of irrigation tank characterised as Farms without Tank Recharge (WoTR); and another sample of farmers sharing groundwater among their relatives characterised as shared well farmers (SWF). In each category a sample of 30 farmers were chosen following random sampling and field data pertaining to crop year 2016-17 were obtained for the analysis.

III

METHODOLOGY

This section highlights the concepts of agronomic maximization of output, economic maximization of net returns, and the method of costing groundwater irrigation by incorporating the reciprocal negative externalities the farmers are continuously facing due to indiscriminate drilling of irrigation wells as also due to cumulative interference leading to increased probability of well failure.

(A) *More Crop Per Drop*

Farmers may follow the agronomic strategy of 'more crop per drop' (MCPD) or follow the economic strategy of 'maximizing net returns per Rupee of water cost'

(MNPW) in cultivating crops. The data on total groundwater 'consumed' by each crop can largely be obtained from field experiments. In this study the data were obtained from farmers regarding groundwater applied to crops through drip irrigation. In drip irrigation, as water is applied to root zone, the evaporation losses as well as return flows are relatively kept to minimum compared with surface irrigation. Hence the difference between groundwater applied and groundwater consumed is not significant. To this extent, this is a limitation of the study as in all studies dealing with drip irrigation. Thus, More Crop Per Drop (MCPD) is given as:

$$\text{MCPD} = \frac{\text{Total output of the crop in Kgs}}{\textit{Total Groundwater applied in M3}} \quad \ldots. (1)$$

(B) *Maximizing Net Returns*

The strategy of maximizing Net returns per Rupee of water cost (MNPW) is to identify crops which fetched the highest net return per rupee of water cost, akin to the point where Marginal Returns equal Marginal cost Accordingly the crops which fetch high net returns per rupee of water cost can be obtained as under:

$$\text{MNPW} = \frac{\text{Net return in Rs}}{\text{Groundwater Irrigation cost in Rs}} \quad \ldots. (2)$$

(C) *Categorisation of Crops*

Based on the water use and the net return per rupee of expenditure obtained, two categories of crops are discerned in this study as under:

1) Low Water Intensive - High Value Crops (LWI-HVC): are crops cultivated using less than 10 acre inches (or ha cms) per acre of the crop yielding a net return of more than one Rupee per Rupee of expenditure.

2) High Water Intensive – Low Value Crops (HWI-LVC) - are those crops cultivated using more than 10 acre inches (or ha cms) per acre yielding a net return of less than one Rupee per Rupee of expenditure.

A conversion factor of 1 acre inch (or 1 ha cm) = 22611 gallons of water is used to mean a volume of 1 inch of water on one acre of land, or one cm of water on one hectare of land, both leading to approximately the same answer as one inch = 2.54 cms and one hectare = 2.5 acres. By using one gallon = 4.54 liters, acre inch can be converted to Cubic Meter. One cubic meter = 1000 liters.

(D) Method of Costing Groundwater Irrigation

Farmers need a thumb rule for choice of crops based on profitability and resource costs. As mentioned earlier, more than 70 per cent of the irrigation is from groundwater in India. Hence it is crucial to cost/value the groundwater resource. In hard rock areas, the information on life /age of irrigation wells is difficult to generalise for a region. The farmers would have invested in several wells on the farm as there is uncertainty regarding the volume of water as well as years of functioning of well/s. The factors *inter alia* aquifer characters, volume of groundwater extraction, electricity supply, markets, road connectivity, availability of labour, degree of cumulative interference, efforts to recharge irrigation borewells and institutional factors such as sharing groundwater well water will shape the economy of groundwater irrigation characterised by both fixed and variable costs.

Due to reciprocal negative externality due to cumulative interference, since the failure of irrigation wells is immanent as well as imminent, groundwater cost will have both the variable cost component of drilling and casing as well as the fixed cost component of pump sets, pipes, installation cost etc. Farmers accordingly are therefore forced to drill new irrigation well/s due to increasing probability of well failure responsible for reduced life and reduced age of irrigation borewells. The variable cost of groundwater is composed of the cost of drilling and casing and varies with the number of wells drilled on the farm which in turn varies with number of year/s well/s functioned. The fixed cost of groundwater is the amortized cost (of pump sets, conveyance structure, drip irrigation and borewell recharge, water storage structure, and electrical installation) as irrigation pump sets and accessories can last for at least ten years.

(i) Variable Cost of Groundwater Irrigation:

The variable cost of drilling and casing is also the variable cost component of borewell irrigation attributable to the negative reciprocal externality due to cumulative interference among irrigation borewells. Farmers are forced to drill additional borewell/s due to increasing probability of initial / premature failure of wells due to which there is reduction in the life / age of wells in hard rock areas. For instance, borewells which used to serve for at least 15 to 25 years are now serving below 5 years. Usually variable cost in groundwater irrigation refers to marginal pumping cost or electricity cost of pumping groundwater. As no electrical meter has been fixed on irrigation borewells in Karnataka, the electricity used for pumping irrigation water is not measured, and usually estimated as a residual after accounting for all metered consumption. Thus, the residual also includes transport and distribution losses. Studies have argued that the variable cost of drilling (Chandrakanth and Patil, 2018) and casing forms a substantial portion of the total cost of groundwater irrigation from borewells and the provision of free electricity is not a windfall gain for farmers as it forms only around 20 per cent to 25 percent of the total cost of irrigation water. In this study the variable cost of groundwater was obtained by amortizing investment on drilling and casing of borewells over the life/age of the borewell. The details of methodology are in the following sections.

(ii) Fixed Cost of Groundwater Irrigation

The fixed cost of groundwater was obtained by amortizing investment on irrigation pump sets, pump house, electrification charges, groundwater storage structure, investment on groundwater delivery pipe, drip / sprinkler irrigation and accessory investment for a period of ten years as these are assumed to last for a decade. The amortized fixed investment was divided by the volume of groundwater extracted in the year of data collection (2017) to obtain the fixed cost of groundwater per ha cm or acre inch. The annual cost of irrigation pertains to each irrigation borewell on the farm and was added across all borewells on farm. This total cost of irrigation was then apportioned for each crop according to the volume of groundwater used in each crop.

(iii) Borewell Failure and Economic Life of Borewell

Initial failure of borewell refers to a borewell which does not yield any groundwater at the time of drilling and thereafter. Subsistence life of borewell refers to the number of years a borewell yielded groundwater up to the Pay Back Period (PBP). Premature failure refers to the borewell which served below the subsistence life or the PBP. Economic life/age of borewell refers to the number of years a borewell yielded groundwater beyond the PBP.

The PBP was obtained by dividing the total investment on drilling, casing, IP set, conveyance structure, storage structure, drip/sprinkler structure, recharge structure, electrification charges of borewell by the annual net returns obtained per farm and indicates the number of years required for the investment to pay for itself. The hypothesis is that an irrigation borewell is considered to have served its purpose, if it has at least paid back the total investment made for the purpose. This implies that PBP indicates the period in which a borewell recovered the investment made.

(iv) Amortized Cost of Borewell

In order to obtain the groundwater irrigation cost, the investments made on different borewells on the farm are amortized as investment on drilling and casing are no longer a fixed cost, since given the increasing probability of well failure, farmers continue to make investments to irrigate crops through new borewells/drillings. This investment is amortized over the average life of the borewell. The amortized cost varies with amount of capital investment, age of the borewell, discount rate, year of construction of borewell. The amortization methodology employed by Diwakara and Chandrakanth (2007) was used in the present study.

Step 1: Compounding the investment on irrigation borewells: Farmers invest on irrigation well/s during different time periods and accordingly, their wells have different vintages. It is crucial to note that the cost of groundwater irrigation should not be computed by considering borewell/s which are currently yielding water as well as the borewells which initially, prematurely failed. In order to bring all the historical costs on par, investments made by the farmer in different years in the economic past, are compounded to the latest year (2018) at a discount rate of two per cent. The justification for using 2 per cent is from Diwakara and Chandrakanth (2007).

Compounded cost of BW = (Historical investment on BW) ×
$(1 + i)^{(2018\text{-year of drilling})}$ ... (3)

Step 2: The compounded investment is divided into the fixed cost component (= irrigation pump sets plus conveyance structure, drip irrigation structure and so on amortizing over ten years), plus the variable cost of drilling and casing the borewell, amortized over the average life of borewell, since farmers lose drilling cost and casing cost once well fails either initially, or prematurely. Hence, these two costs are separately amortized to obtain the yearly fixed and variable cost of irrigation borewell. As mentioned earlier, the cost of drilling and casing are considered as variable cost since farmers are forced to invest in new well/s after the failure of previous well/s either prematurely or initially.

Step 3: Amortized cost of irrigation

Amortized cost of irrigation = (Amortized cost of borewell + Amortized cost of pump set + Amortized cost of conveyance + Amortized cost of over ground structure + annual repairs and maintenance cost of pump set and accessories (P and A) given by

Amortized cost of BW = (Compounded cost of BW) $\times \frac{(1+i)^{AL} \times 1}{(1+i)^{AL} - 1}$ .... (4)

Here AL= Average age or life of borewell i = discount rate considered at 2 per cent

Amortized cost of P and A = (Compounded cost of P and A) $\times \frac{(1+i)^{10} \times 1}{(1+i)^{10} - 1}$ .... (5)

Amortized cost of conveyance structure (CS) = (Compounded cost of CS)
$\times \frac{(1+i)^{10} \times 1}{(1+i)^{10} - 1}$ .... (6)

Amortized cost of micro irrigation structure (MIS)
(Compounded cost of MIS)$\times \frac{(1+i)^{10} \times 1}{(1+i)^{10} - 1}$ …. (7)

The working life of pump-sets and accessories (P and A) and conveyance structure (CS) was considered to be ten years as their economic life. The usual mode of conveyance of groundwater is through PVC pipe. The working life of micro (drip/sprinkler) irrigation structure (MIS) was considered to be 10 years since farmers usually replace them after 10 years, where, i = Discount rate considered at 2 per cent

Compounded cost of pump set and accessories
= (Historical cost of P and A) × $(1 + i)^{(2018\text{-year of installation of P and A})}$ ….(8)

Compounded cost of CS = (Historical cost of CS) ×
$(1 + i)^{(2018\text{-year of installation of CS})}$ ….(9)

Compounded cost of MIS = (Historical cost of MIS)
× $(1 + i)^{(2018\text{-year of installation of MIS})}$ ….(10)

(v) Fixed Cost of Irrigation Well

The fixed cost of groundwater is depreciation or amortized cost of investment on pump sets, conveyance structure, pump house, drip irrigation equipment, borewell recharge structure, water storage structure, electrical installation, field channel and so on. As mentioned earlier, fixed cost of well excludes the cost of drilling and casing, which is taken as variable cost due to increasing probability of well failure in hard rock areas. The investment is amortized at 2 per cent for around 10 years assumed to be taken as the life of fixed assets in irrigation.

Fixed cost of groundwater/ha cm or acre inch = The amortized fixed investment / the volume of groundwater extracted in the year of data collected.

The total annual cost of irrigation = amortized Variable cost + amortized Fixed cost

Cost of irrigation per acre-inch = (Total annual cost of irrigation) / (volume of water used for the crop in acre inches of GW used) …. (11)

The volume of groundwater used for irrigation in each crop (acre inches) in Drip irrigation is measured as {Number of drips or emitters for the cropped area x groundwater discharged per emitter per hour (liters per hour) x No. of hours of drip irrigation of the cropped area for one irrigation x frequency of irrigations per month (in number) x Duration of crop irrigated in months /4.54 litres per gallon /22611 gallons to make one acre inch}

Similarly, the groundwater used for irrigation in each crop (acre inches) in sprinkler irrigation = {Number of sprinklers for the cropped area x No. of hours of sprinkler irrigation to irrigate the cropped area for one irrigation x groundwater discharged per sprinkler (in liters per hour) x frequency of irrigation per month (in number) x Duration of crop irrigated in months/4.54 litres per gallon /22611 gallons to make one acre inch}. One acre inch is equivalent to 22611 gallons or 3630 cubic feet and one cubic feet is equivalent to 28.32 litres. The volume of total groundwater used per farm in acre inches of groundwater used in all seasons across all crops including perennial crops is ultimately measured. This measurement was relatively accurate compared to equating one inch of discharge as equal to 1000 gallons per hour, 2 inches of discharge as 2000 gallons per hour and so on as usually assumed in groundwater yield measurements on farms without micro irrigation system.

(vi) Externality Cost

In hard rock areas, each farmer’s pumping of groundwater is not independent of the other, but is interdependent on the extraction by neighbouring well(s) at a time and over time. This results in reciprocal negative externality, as all the users of groundwater impose external costs on all other users simultaneously and over time. In the case of unidirectional externality, a farmer by drilling deeper and/or increasingly extracting groundwater inflicts externality on others and on himself or herself at a time and over time due to interference of well/s. However, over time, other farmers pumping groundwater impose external costs on all others, including upon themselves due to cumulative interference, and this is the phenomenon of reciprocal externality Dasgupta

(1982) used in this study. This concept is similar to externality in traffic congestion. The negative externality per borewell is computed as under:

Externality cost per borewell or negative externality cost per borewell or reciprocal negative externality cost per borewell =

(Amortized per functioning well - Amortized cost per well) on the farm.

Amortized per functioning well = Total amortized cost divided by the number of functioning wells in the farm;

Amortized cost per well = Total amortized cost divided by all the wells in the farm.

Thus, if there are no failed wells (i.e., if there are no initial failures and/or premature failures), then all wells are functioning and there is no externality. On the contrary, if there are failed wells, then the hypothesis is that the well failure is / are due to reciprocal negative externality and hence the difference between the Amortized cost per functioning well and the Amortized cost per well will reflect the magnitude of negative externality, since the amortized cost per functioning well will always be higher than amortized cost per well indicating existence of externality.

(vii) Cost of Cultivation

The cost of cultivation is obtained as the sum of cost of human labour, bullock labour, machine hours, seeds, fertilisers, manures and application cost, plant protection measures, bagging, and transporting, interest on working capital at 7 per cent, risk premium at 2 per cent and management cost at 5 per cent on variable cost. The irrigation cost for each crop is the cost per acre inch of irrigation multiplied by the total number of acre inches of irrigation provided for the crop.

(viii) Returns

Gross return is the value of the output and the by-product at the prices realised by the farmers added up for each crop across gross irrigated area in a year. Net returns from borewell irrigation are the gross returns from gross irrigated area minus the cost of production of all crops in a year.

The Gross return per rupee of expenditure = $\frac{\text{Gross return}}{\text{Total cost}}$

Net returns from irrigation are equal to Gross Returns from gross irrigated area minus the cost of production of all crops. Gross returns per farm comprised of returns from irrigated farming, rainfed farming, sericulture and livestock farming. Similarly, net returns per farm for groundwater was computed by deducting the gross returns from irrigated crops, rainfed crops and livestock component from totalcost of cultivation of crops including groundwater cost and cost of rearing livestock.

Net returns from irrigation = (GR from GIA) – (the cost of production of all crops)

Net returns over the Variable cost = Gross returns – Variable Cost

Net returns including cost of irrigation water = Gross returns – Total Cost including cost of irrigation water

Net returns excluding water cost= Gross returns – Total Cost excluding cost of irrigation water

Net Returns per rupee of expenditure = Net returns/Total cost

IV

RESULTS AND DISCUSSION

The LWI-HVC crops in the study area were ridge gourd, ash gourd, carrot, beans, brinjal, cucumber, onion, red gram vegetable, field bean, lab lab bean, chili, green leafy vegetables - palak, amaranthus, dill sabbasige, coriander; flowers- chrysanthemum, marigold and the perennial mulberry. The HWI-LVC crops were capsicum, knol khol, cabbage, potato, tomato, rose, ginger, grapes. These crops are relatively high water using but yielding low net return (Table 1).

TABLE 1: CROP CATEGORIES BASED ON WATER USED AND NET RETURNS REALIZED

Crop (1)	Groundwater used to cultivate one acre of crop (in M3) (2)	Net return per Rupee of total cost of cultivation (BC Ratio) (3)
Low water intensive high value crops		
Marigold	991	1.89
Mulberry	1737	1.63
Chrysanthemum	1748	1.30
Palak	504	1.21
Papaya	1303	1.10
Coriander	553	1.05
Amaranthus	493	0.80
Dill (sabseege)	528	0.71
Carrot	893	0.65
Ash gourd	922	0.57
Ridge gourd	1193	0.49
Beans	947	0.43
Beetroot	1106	0.41
Dolichos lab	1071	0.39
Brinjal	769	0.37
Onion	972	0.34
Cucumber	902	0.22
Field bean	754	0.19
Red gram	685	0.10
Chili	1253	0.10
High Water Intensive Low Value Crops		
Capsicum	1329	0.35
Cabbage	1001	0.15
Tomato	1377	0.13
Rose	3210	0.10
Ginger	2307	0.10
Grapes	1844	0.10
Potato	1112	0.07
Knol Khol	1169	0.02

(A) Equality in Irrigation Assets

The size of holding of sample farmers ranged from 1.5 acres to 30 acres across the three sample categories. Marginal and small farmers formed 50 per cent, 60 per cent and 56 per cent of the total in each category of sample farmers. Therefore, among borewell irrigated farmers, the small and large farmers have equal ownership as small and marginal farmers did not deter in investments on the risky borewell irrigation despite the uncertain nature of striking groundwater as indicated by the low probability of well success. The results of the study pertaining to access to irrigation indicated equality in holding size across the three categories of farmers using drip irrigation (Table 2). The technology of drip irrigation thus enabled the marginal and small farmers to have access to irrigation despite high investments in realising remunerative returns. The net irrigated area per farm ranged from 2.73 acres to 3.41acres while the gross irrigated area per farm ranged from 5.33 to 5.98 acres per farm. The gross irrigated area formed 71 per cent, 67 per cent and 63 per cent of the gross cultivated area across the three categories. Thus the technology of drip irrigation enabled farmers to irrigate at least 60 per cent of their gross cultivated area. This is impressive considering that the net irrigated area forms around 50 per cent of the land holding.

TABLE 2: LAND HOLDING, AREA IRRIGATED AND CULTIVATED BY SAMPLE FARMERS

(area in acres)

Particulars	Farms WoTR	Farms WTR	SWF
(1)	(2)	(3)	(4)
Average size of land holding(range)	6.01	6.40	6.61
	(1.5-17)	(1.5-30)	(1.5-25)
Gross cultivated area (range)	8.38	7.98	9.22
	(3.5-15)	(3-25.5)	(1-31)
Gross irrigated area (range)	5.98	5.33	5.86
	(2-14)	(1-11.5)	(1-15)
Net irrigated area (range)	3.41	3.02	2.73
	(0.75-14)	(0.5-15)	(0.5-8)
Net rainfed area (range)	2.57	3.46	4.38
	(0-8)	(0-14)	(0-16)
No. of marginal and small farmers (0 -5	15	18	17
acres)	(50)	(60)	(56.70)
No. of medium farmers (5-25acres)	12	7	9
	(40)	(23)	(30)
No. of large farmers (>25 acres)	3	5	4
	(10)	(17)	(13.30)

Note: Figures in the parentheses indicate per cent to total. WTR = with tank recharge, WoTR = without tank recharge, SWR = Sharing water farmers;

The small and marginal farmers formed about 55 per cent of the sample while large farmers formed 45 per cent. But, the average gross irrigated area of both the categories of farmers was around 5 acres with no substantial variation in crop pattern dominated by vegetables, greens, flowers and fruits due to demand from the Bengaluru metropolitan. Thus, due to relatively uniform gross irrigated area and relatively uniform crop pattern, the groundwater cost for different category of farmers was also relatively uniform. In addition, in Karnataka only 1 per cent of the food crops are procured as against more than 90 per cent procurement in Punjab and Haryana at MSP. Thus, market forces have wielded a relatively strong influence on the crop pattern in the study area in Karnataka which promoted crop diversification, while in Punjab and Haryana, with more than 90 per cent of the food crops procured at MSP, crop diversification is severely affected promoting mono-cropping of rice–wheat by overexploiting groundwater.

B. *Crop Economics Including Cost of Irrigation*

Inclusion of cost of irrigation water is a crucial aspect of irrigation economics since conventionally land, labour, capital and management were the only considered/ recognised factors of production. The increasing economic scarcity of groundwater is responsible for farmers to include groundwater as an economic resource. The net returns from crops with and without cost of groundwater provides information on the role of groundwater resource in shaping crop economy of irrigated farmers.

The area allocation and net returns of the crop classification across the sample farms categories of are indicated in Table 3. In the farms WoTR, 38 per cent of area was under high water intensive low value crops followed by low water intensive high value crops (31 per cent) (flowers, green leafy vegetables, vegetables) and 31 per cent of its area for rainfed crops. The average net return including cost of groundwater per acre was the highest for LWI-HVC (Rs.29950) and the lowest for HWI-LVC (Rs.16770).

In the WTR farms, about 40 per cent of the gross cultivated area were allocated to LWI-HVC realising net returns per acre including water cost of Rs.40517 and 28 per cent of area were allocated for HWI-LVC realizing net return per acre of Rs.15000. The cropping pattern for farms WTR was comparable with that of the SWF who largely relied on LWI-LVC.

TABLE 3: DETAILS OF CROPPED AREA, NET RETURNS OF DIFFERENT CATEGORY OF CROPSACROSS SAMPLE FARM CATEGORIES IN KARNATAKA

Particulars (1)	WoTR (2)	WTR (3)	SWF (4)
Total area allocated to LWI – HVC (acres)	77.5 (31)	94 (40)	94 (34)
Area allocated to LWI-HVC crops per farm (acres)	2.87	3.24	3.25
Net return including irrigation water cost per acre (Rs.)	29950	40517	27612
Net return excluding irrigation water cost per acre (Rs.)	68387	73891	65290
Total area allocated to HWI-LVC (acres)	94 (38)	68 (28)	76 (27)
Area allocated to HWI-HVC crops per farm (acres)	3.36	2.51	2.9
Net return including irrigation water cost per acre (Rs.)	16770	15002	12848
Net return excluding irrigation water cost per acre (Rs.)	61058	62732	57530
Total area allocated to rainfed crops (acres)	77 (31)	76 (32)	105 (38)
Area allocated to rainfed crops per farmer (acres)	3.08	3.16	4.26
Net return per acre (Rs.)	25402	36180	45386

Notes: The details of LWI-HVC and HWI-LVC and crops is provided in Table 1; WoTR- Farmers without tank recharge, WTR: Farmers with tank recharge, SWF: Shared well farmers; Figures in parentheses indicate per cent to the total.

The SWF who share groundwater with their siblings allocated 34 per cent of the area for LWI-HVC (flowers, green leafy vegetables) earning net return of Rs.27612 per acre. The lowest area was allocated to HWI-LVC (27 per cent) earning the least net return per acre of Rs.12848.

It is crucial to note that in the case of LWI-HVC, with the inclusion of cost of groundwater irrigation, the net returns get reduced by 56 per cent in WoTR farms, by 48 per cent in WTR farms and by 58 per cent in SWFs. In the case of HWI-LVC, with the inclusion of cost of groundwater irrigation, the net returns get reduced by 72 per cent in WoTR farms, by 76 per cent in WTR farms, and by 69 per cent in Shared well farms. This shows that net returns are over-estimated to the tune of at least 50 per cent to 70 per cent in different crops by excluding the cost of groundwater resource in the cost of cultivation of crops. Thus farmers need to properly account for cost of groundwater irrigation which helps in appropriate crop choice and sustainable use of groundwater on their farms (Table 3).

(C) *Should Farmers Grow 'More Crop Per Drop' or Maximize Net Returns?*

The differences between the two are reflected in crop choice (Table 4). If farmers follow the strategy of More crop per drop (MCPD), then they need to cultivate

TABLE 4: COMPARISON OF MCPD AND MNPW CROPS IN KARNATAKA

Crops (1)	Groundwater used to cultivate one acre of the crop (in M3) (2)	More Crop Per Drop criterion (kgs per M3 of groundwater) MCPD (3)	Net return per rupee of groundwater cost with MNPW criteria (4)
Low water intensive high value crops			
Marigold	990.90	6.57	4.44
Mulberry	1737.15	7.14	2.15
Chrysanthemum	1748.46	2.55	3.35
Palak	503.67	13.50	3.39
Papaya	1303.38	14.12	4.08
Coriander	553.01	6.37	3.21
Amaranthus	493.39	6.89	6.07
Dill (sabseege)	528.34	6.87	2.41
Carrot	893.25	9.36	2.80
Ash gourd	922.03	11.39	2.10
Ridge gourd	1193.40	4.58	1.86
Beans	946.70	5.70	2.52
Beetroot	1106.02	7.46	1.96
Dolichos lab	1071.07	3.87	2.09
Brinjal	768.87	9.26	1.88
Onion	972.39	5.96	1.83
Cucumber	902.50	5.47	1.46
Field bean	754.48	3.50	1.41
Red gram	684.58	3.59	1.21
Chili	1253.01	5.15	1.02
High water intensive low value crops			
Capsicum	1329.07	4.89	2.11
Cabbage	1001.17	11.99	1.47
Tomato	1377.39	10.02	1.51
Rose	3210.13	1.45	1.23
Ginger	2306.61	1.91	1.30
Grapes	1844.05	4.66	1.32
Potato	1112.19	8.63	1.24
Knol Khol	1168.72	5.00	1.04

Note: MCPD: More crop per drop; MNPW: Maximum net return per rupee of groundwater cost.

Papaya which ranks the first producing 14.12 kgs per cubic meter of groundwater followed by palak (13.5), Ash gourd (11.39), Brinjal (9.26), Mulberry (7.14) from among LWI-HWC realising net returns per acre ranging from Rs. 27612 per acre to Rs. 40517, and Cabbage (11.99 kgs), Tomato (10.02), Potato (8.63), Knol Khol (5.00) from among HWI-LVC.

On the other hand, if farmers follow the strategy of maximizing net returns per rupee of groundwater cost (MNPW), then they need to cultivate Amaranthus (Rs.6.07) followed by Marigold (4.44) Papaya (4.08), Palak (3.39), Chrysanthemum (3.35), from among LWI-HVC, and Capsicum (2.11), Cabbage (1.47), Tomato (1.47), Rose (1.23), Ginger (1.30), Grapes (1.32) from among HWI-LVC (Table 4). Since groundwater is scarce, the farmers should choose MNPW crops and not MCPD crops.

(D) *Crop Economics Including the Cost of Groundwater Irrigation*

It is crucial to note that in the case of low water intensive high value crops, with the inclusion of cost of groundwater irrigation, the net returns get reduced by 56 per cent in farms WoTR, by 48 per cent in farms WTR and by 58 per cent in SWF. In the case of High water intensive low value crops, with the inclusion of cost of groundwater irrigation, the net returns get reduced by 72 per cent in farms WoTR, by 76 per cent in farms WTR, and by 69 per cent in SWF. This shows that currently, the net returns are over estimated to the tune of at least 50 per centto 70 per cent in different groundwater irrigated crops, since farmers are notaccounting for the cost of groundwater irrigation in their estimation of cost ofcultivation. This analysis reflects that farmers need to properly account for cost ofgroundwater irrigation and accordingly take measures towards sustainable use of groundwater on their farms (Table 5 (A) and 5(B)).

(E) *Cost of Cultivation of LWI-HVC in Karnataka*

The cost of cultivation per acre of LWI HVC ranges from Rs.25000 for green leafy vegetables to Rs.one lakh for beans, and papaya. In the cost of cultivation the largest component was for irrigation water of Rs.30000 per acre (41 per cent) followed bylabour cost of Rs.13000 (18 per cent) and marketing cost of Rs.10000 per acre (13 per cent). It is crucial to note that the labour cost component has the reduced share of expenditure of around 18 per cent since the farmers are adopting drip irrigation, which not only saves around 50 per cent of the water use but also saves substantialexpenditure on labour.

Considering the range of LWI-HVC cultivated by farmers, the top ten crops providing the highest net returns per acre inch of groundwater are marigold (Rs.11463/ acre inch) followed by papaya (Rs.10256/ acre inch), palak (Rs.7968/ acre inch), Chrysanthemum (Rs.7831/ acre inch), coriander (Kottambari soppu) (Rs.7363/ acre inch), Carrot (Rs.6010 / acre inch), Beans (Rs.5060/ acre inch), Dill(Rs.4710 per acre inch), Mulberry (Rs.3847/ acre inch), and Amaranthus (Rs.3800/acre inch) (Table 5 A and 5 B).

TABLE 5 (A): COST OF CULTIVATION (PER ACRE) FOR LWI-HVC IN KARNATAKA

Crop	Seed material in kg/ seedlings		Labour (man days)		Bullock pair days		Machine labour in hours		FYM in tractor loads		Fertiliser cost	PPC
	Qty (2)	Rs. (3)	Qty (4)	Rs. (5)	Qty (6)	Rs. (7)	Qty (8)	Rs. (9)	Qty (10)	Rs. (11)	Rs. (12)	Rs. (13)
(1)												
Amaranthus	1.00	1100	20.80	6240	2.00	2000	6.00	5700	0	0	1050	2000
Coriander	14.38	4548	22.82	7576	2.01	1854	4.38	3960	1.13	2769	1823	1286
Sabbasige	1.14	3417	19.45	6457	2.09	1810	4.00	3600	1.17	2870	1823	1574
Palak	10.00	2350	32.33	11024	1.00	980	3.34	3450	1.16	2540	2440	860
Red gram	10.67	760	22.67	7480	0.67	567	2.33	2100	1.20	2933	1583	1650
Chrysanthemum	45000	7158	112.00	38233	2.95	2642	4.04	3221	3.22	7895	3956	5263
Marigold	0.90	5550	40.82	13552	2.00	1267	2.67	2400	1.95	4783	7356	5417
Mulberry	11450	6057	25.49	8412	1.95	2192	0	0	3.34	8156	3451	887
Papaya	1050	9975	86.00	28552	2.00	1860	3.00	2700	5.00	12210	16850	22150

Crop	Marketing cost	Water used (acre inches)			Total cost	Output	Price per quintal	TR	NR including water cost	NR excluding water cost
(1)	Rs. (14)	Vol (15)	VC in Rs (16)	FC in Rs. (17)	Rs. (18)	Quintal (19)	Rs. (20)	Rs. (21)	Rs. (22)	Rs. (23)
Amaranthus	2600	4.80	1613	1968	22658	34.00	1200	40800	18142	21723
Coriander	10658	5.38	14526	3416	37890	35.23	2200	77508	39618	57560
Dill sabseege	9437	5.14	13878	3264	34252	36.35	1608	58459	24207	41349
Palak	5600	4.90	13230	3112	32356	68.00	1050	71400	39045	55386
Red gram	3420	6.66	17982	4229	41446	24.57	1860	45700	4255	26857
Chrysanthemum	22947	17.01	45927	10801	102116	44.58	5400	235326	133210	189938
Marigold	12042	9.64	26028	6121	58488	65.12	2600	169000	110512	142661
Mulberry	0	16.90	45630	10732	39886	124.00	846	104904	65018	121379
Papaya	16000	12.68	34236	8051.8	118349	184.00	1350	248400	130051	172339

Source: Anitha (2020).

Notes: Vol=Volume of water in acre inches, VC=Variable cost, FC=Fixed cost, NR= Net returns, FYM=Farm yard manure, PPC=Plant protection chemicals. LWI-HVC: Low Water intensive – high value crops.

TABLE 5 (B): COST OF CULTIVATION PER ACRE FOR LWI-HVC IN KARNATAKA

Crop	Seed material in Kg/ seedlings		Labour (man days)		Bullock pair days		Machine labour in hours		FYM in tractor loads		Fertilizer cost	PPC
	Qty	Rs.	Qty	Rs.	Qty	Rs.	Rs.	Rs.	Qty	Rs.	Rs.	Rs.
	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Dolichos lab	14.53	1744	48.45	16106	2.00	1882	2.94	2647	3.39	8294	15425	3329
Beetroot	2.51	3157	33.87	11689	2.03	1980	3.61	3420	2.70	6623	6430	2262
Field bean	8.08	727	34.6	11487	1.08	1008	2.85	2500	1.83	4492	1789	889
Brinjal	0.35	3420	28.12	9640	2.27	2111	3.60	3240	1.52	3714	2665	1138
Carrot	2.24	6450	31.62	10640	1.76	1731	3.78	3556	3.30	8095	2652	2204
Cucumber	1.26	878	30.83	10234	2.21	2041	3.31	3170	1.50	3676	2684	2343
Ash gourd	1.25	1300	23.50	7285	2.69	2500	4.00	3600	1.51	3700	1200	775
Beans	18.16	4995	75.15	25830	1.15	1017	3.09	2757	1.28	3147	6169	7257
Onion	10.21	3267	39.89	13084	1.12	985	3.10	2985	1.63	4000	5200	5620
Ridge gourd	2.54	1250	32.95	10803	1.44	1368	3.14	2886	1.12	2738	2778	1297
Chilli	0.42	2549	31.99	10557	1.38	1485	2.97	2930	1.90	4651	4003	3590

Crop	Marketing cost	Stalking charges	Water used (acre inches)			Total cost	Output in	Price per quintal	Total returns	Net Return including water cost	Net Return excluding water cost
	Rs.	Rs.	Vol	VC (Rs.)	FC in Rs.	Rs.	Quintal	Rs.	Rs.	Rs.	Rs.
	(14)	(15)	(16)	(17)	(18)	(19)	(20)	(21)	(22)	(23)	(24)
Dolichos lab	12471	0	10.42	28134	6617	96649	41.50	3240	134460	37811	72562
Beetroot	12340	0	10.76	29052	6833	83786	82.56	1430	118061	34275	70160
Field bean	5680	0	7.34	19818	4661	53051	26.38	2390	63048	9997	34476
Brinjal	8970	0	7.48	20196	4750	59844	71.22	1150	81903	22059	47005
Carrot	15743	0	8.69	23463	5518	80052	83.56	1583	132275	52224	81205
Cucumber	7852	0	8.78	23706	5575	62159	49.40	1530	75582	13423	42704
Ash gourd	7250	0	8.97	24219	5696	57525	105.00	860	90300	32775	62690
Beans	14473	12340	9.21	24867	5848	108700	54.00	2876	155304	46604	77319
Onion	10444	0	9.46	25542	6007	77134	58.00	1780	103240	26106	57655
Ridge gourd	5460	0	11.61	31347	7372	67299	54.62	1842	100610	33311	72030
Chilli	9014	0	12.19	32913	7741	79433	64.5	1245	80302	870	41524

Source: Anitha (2020).

Notes: Vol=Volume of water in acre inches, VC=Variable cost, FC=Fixed cost, NR= Net returns, FYM=Farm yard manure, PPC=Plant protection chemicals; LWI-HVC: Low water intensive – high value crops.

(F) *Cost of Cultivation of HWI-LVC in Karnataka*

Cost of cultivation of HWI-LVC for different crops is presented in Table 6. The cost of cultivation of per acre HWI-LVC ranges between Rs.88000 for Knol Khol and Rs.2.32 lakh for rose. The cost of cultivation of HWI-LVC is higher thanthe LWI HVC with higher consumptive use of groundwater per acre with lower netreturn per rupee of expenditure. The component wise cost of cultivation of HWI- LVC, the cost of groundwater irrigation accounts for the highest being Rs.54000 forming 34 per cent of the total cost of cultivation followed by labour cost of Rs.25000 forming 16 per cent and the marketing cost of Rs.24000 forming 15 per cent (Figure 1). Therefore in the groundwater scarce areas, the crops under HWI-

LVC category are not economically viable because these crops require higher water, higher investment and earning low net returns per rupee of expenditure (1:0.68). Farms WoTR allocating substantial area for HWI-LVC crops to the tune of 38 per cent leads to unsustainable water use. The sample farms WTR allocated 28 per cent and SWF allocated 27 per cent of the area, comparatively lower per centage of area for HWI-LVC. It is crucial to note that the area under these crops needs to be reduced and shifted towards LWI-HVC due to groundwater scarcity. However farms cultivating HWI-LVC, with the highest net returns per acre inch ofgroundwater from Capsicum (Rs.3689/ acre inch) followed by Tomato (Rs. 1715/acre inch), Cabbage (Rs. 1563/acre inch), Grapes (Rs. 1074/ acre inch), Ginger (Rs.1000/ acre inch), Potato (Rs.813/ acre inch), and Rose (Rs.752 /acre inch)

V

CONCLUSIONS

This paper highlights the importance of more crop per drop vis-à-vis maximizing net returns as criteria for choice of crops by farmers in groundwater irrigation. The choice of crops in both the criteria differs widely since groundwateris becoming increasingly scarce in hard rock areas hence requiring the cost of groundwater to be included in the cost of cultivation of crops. The cost of groundwater irrigation including the fixed cost and variable cost components havebeen provided for each of the 35 crops cultivated by the farmers in order to sensitizeregarding the economic scarcity value of groundwater. If the farmers choose to maximize their net returns per Rupee of groundwater expenditure then they need to cultivate Amaranthus (Rs.6.07) followed by Marigold (4.44) Papaya (4.08), Palak (3.39), Chrysanthemum (3.35), from among LWI-HVC, and Capsicum (2.11), Cabbage (1.47), Tomato (1.47), Rose (1.23), Ginger (1.30), Grapes (1.32) from among HWI-LVC (Table 4). However, if the farmers choose More crop per drop of water strategy, then they need to cultivate Papaya which ranks the first producing 14.12 kgs per cubic meter of groundwater followed by Palak (13.5), Ash gourd (11.39), Brinjal (9.26), Mulberry (7.14) from among low water intensive, high value crops and cabbage (11.99

TABLE 6: COST OF CULTIVATION PER ACRE FOR HWI-LVC CROPS IN KARNATAKA

Crop	Seed material in Kg/ seedlings		Labour (man days)		Bullock pair days		Machine labour in hours		FYM in tractor loads		Chemical fertilizer cost	PPC
	Qty	Rs.	Qty	Rs.	Qty	Rs.	Qty	Rs.	Qty	Rs.	Rs.	Rs.
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Rose	4450	53400	98.14	32255	3.5	3150	4.38	3938	2.37	5800	7298	7000
Ginger	152.5	9913	74.75	24668	0	0	5.00	4500	7.12	17450	17600	23250
Grapes	203.94	4201	124	42135	0	0	13.55	10614	2.48	6068	9831	37831
Cabbage	0.54	5043	34.67	11510	1.74	1723	3.74	3202	2.43	5714	8450	18650
Potato	1270.55	30480	38.71	13200	2.24	2230	3.87	3585	1.95	4773	5834	5676
Knol Khol	1.12	5726	37.11	12247	2.24	2078	2.95	2732	1.49	3645	6244	7865
Capsicum	0.36	6480	64.54	21427	3.06	3059	5.53	4889	3.81	9345	6432	19412
Tomato	7408	5574	138.23	45702	2.3	2352	3.31	3018	2.44	5976	14823	21854

Crop	Marketing cost	Stalking charges	Water used (acre inches)			Total cost	Output	Price /quintal	TR	NR including water cost	NR excluding water cost
(1)	Rs. (14)	Rs. (15)	Volume in acre inches (16)	VC in Rs. (17)	FC in Rs. (18)	Rs. (19)	in quintal (20)	Rs. (21)	Rs. (22)	Rs. (23)	Rs. (24)
Rose	15250	0	31.23	84321	19831	232243	46.50	5500	255750	23507	127659
Ginger	56150	0	22.44	60588	14249	228368	44.00	5700	250800	22432	97269
Grapes	28670	0	17.94	48438	11392	199180	86.00	2540	218440	19260	79090
Cabbage	18000	0	9.74	26298	6185	104775	120.00	1000	120000	15225	47708
Potato	18935	0	10.82	29214	6871	120798	96.00	1350	129600	8802	44887
Knol Khol	10105	0	11.37	30699	7220	88561	58.45	1540	90013	1451	39371
Capsicum	23059	0	12.93	34911	8211	137225	65.00	2845	184925	47701	90822
Tomato	24683	13550	13.4	36180	8509	182221	138.00	1487	205206	22985	67674

Source: Anitha (2020).

Note: Vol=Volume of water in acre inches, VC=Variable cost, FC=Fixed cost, NR= Net returns, FYM=Farm yard manure, PPC=Plant protection chemicals HWI-LVC: High water intensive – low value crops.

kgs), tomato (10.02), potato (8.63), Knol Khol (5.0) from among high water intensive, low value crops. Since scarcity of groundwater is immanent, farmers should choose crops which maximize net returns per rupee of total expenditure which also includes cost of groundwater irrigation rather than the More crop per drop strategy, which does not cost the groundwater irrigation, and merely maximises output rather than net returns to farmers.

It is crucial to note that farmers in Punjab, Haryana, by largely following rice-wheat mono-cropping by utilising three times higher groundwater used by Karnataka, are realising a maximum of net return of Rs.50,000 per acre (without accounting for cost of groundwater), while Karnataka farmers by utilising one-third of groundwater used by Punjab Haryana farmers, by following drip irrigation and conserving both groundwater and labour, are realising net returns of Rs.1.13 lakhs per acre (by accounting for cost of groundwater) which is twice that of Punjab – Haryana farmers. This study has lessons for farmers within Karnataka and outside Karnataka especially for the Punjab-Haryana farmers.

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