More Crop Per Drop: A Myth of Groundwater Irrigation

by S. Anitha and M.G. Chandrakanth

Cover page

Title: **More Crop Per Drop: A myth of groundwater irrigation**

Authors: **S Anitha [1]** and **M G Chandrakanth[2]**

Date: 30/06/2021

Abstract: Produce 'more crop per drop' of water has been an advocacy perhaps assuming that water is a free resource. As 70% of India's irrigation is by groundwater resource, and as extracting and pumping groundwater resource through borewells is increasingly becoming expensive, should farmers adopt 'more crop per drop' as a strategy? Field data from drip irrigation farmers of Karnataka have been used measuring volume of groundwater applied in cultivation of crops as well as investment in irrigation wells for each crop on the farm. The expenditure incurred on groundwater extraction and pumping has been added to the cost of cultivation of crops. Crops ranking on 'more crop per drop' were *inter alia* Papaya (14.12 kgs per M^3 of water) followed by Palak (13.5), Cabbage (11.99), Ashgourd (11.39), Tomato (10.02), while crops ranking on 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). Thus, 'more crop per drop' is a myth and farmers need to be sensitized to choose crops which maximize net returns per rupee of water as cost of groundwater is increasing due to reciprocal negative externalities caused by cumulative interference of irrigation wells.

Affiliations (usually as footnotes):

[1]Rajeev Gandhi National Fellow, Department of Agricultural Economics, University of Agricultural Sciences Bengaluru 560065 Karnataka, India

[2] Former Director, Institute for Social and Economic Change, Bengaluru 560072, Karnataka, India

Keywords- More Crop Per Drop, fixed cost, variable cost of groundwater, borewell irrigation

More Crop Per Drop: A myth of groundwater irrigation

S Anitha [1] and M G Chandrakanth[2]

[1] Rajeev Gandhi National Fellow, Department of Agricultural Economics, University of Agricultural Sciences Bengaluru 560065 Karnataka, India
[2] Former Director, Institute for Social and Economic Change, Bengaluru 560072, Karnataka, India

Corresponding author: anu.s.naik@gmail.com

Abstract

Produce 'more crop per drop' of water has been an advocacy perhaps assuming that water is a free resource. As 70% of India's irrigation is by groundwater resource, and as extracting and pumping groundwater resource through borewells is increasingly becoming expensive, should farmers adopt 'more crop per drop' as a strategy? Field data from drip irrigation farmers of Karnataka have been used measuring volume of groundwater applied in cultivation of crops as well as investment in irrigation wells for each crop on the farm. The expenditure incurred on groundwater extraction and pumping has been added to the cost of cultivation of crops. Crops ranking on 'more crop per drop' were *inter alia* Papaya (14.12 kgs per M^3 of water) followed by Palak (13.5), Cabbage (11.99), Ashgourd (11.39), Tomato (10.02), while crops ranking on 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). Thus, 'more crop per drop' is a myth and farmers need to be sensitized to choose crops which maximize net returns per rupee of water as cost of groundwater is increasing due to reciprocal negative externalities caused by cumulative interference of irrigation wells.

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

Preamble

Agriculture is the largest user of water worldwide. Water is not only the elixir of life, but also elixir of agriculture. Given that groundwater irrigation supports 70 % of India's agriculture, sustainable use of groundwater is crucial and vital considering the ever-increasing users and uses. Focussing on technologies to achieve real efficiency gains and real water savings, since 1996, the International Water Management Institute (IWMI) has been emphasizing on growing more food with the same or less amount of water to achieve increase agricultural water productivity terming it as 'More Crop Per Drop' (MCPD) (https://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub169/rr169.pdf). Further, the Sustainable Development Goal (SDG) 6.4 focusses on water-use efficiency. Following MCPD, the Government of India through the Kissan Sinchayi Yojana (https://pmksy.gov.in/microirrigation/index.aspx) is advocating farmers to grow 'more crop per drop' of water. Thus, MCPD is being promoted to increase crop productivity per unit volume of water. It is crucial to appreciate that MCPD is an agronomic recommendation to grow more, to produce more per unit of a resource. Obviously, this criterion focusses more on productivity, irrespective of the cost of scarce water resource.

The aim of this article is to present, analyse and draw lessons from field based study on estimation of economic returns for farmers by using the MCPD strategy and to compare this strategy with that of maximizing net returns per Rupee of water (MNPW) in order to explore which of the strategies benefit the farmers the most for the benefit of farmers, researchers and policy makers. This study is new and all the results are based on the latest doctoral research endeavour (Anitha, 2020).

The article has the following sections. Section I discusses the problem and objective, Section II, the concepts of agricultural water productivity, Section III groundwater situation in India in the context of green revolution, Section IV, the sampling framework, Section V the methodology used, Section VI discusses the results of the study including whether farmers should follow More crop per drop' strategy or maximize net returns strategy, Section VII the sources of income of farmers and concludes with Section VIII. The various acronyms used in this study are in Annexure.

I. Problem and Objective

Largely IWMI and SDG by focussing on MCPD have relegated the resource economics of scarce groundwater resource since MCPD being an agronomic criterion almost assumes that groundwater is available as a free resource. But groundwater situation in India is grim. Cost of Groundwater resource is colossal due to factors *inter alia* rising probability of initial, premature borewell (BW) failures, negative externality due to increasing cumulative interference among irrigation borewells, over-exploitation of groundwater, provision of electrical energy at zero cost to pump groundwater for irrigation, all resulting in frequent investments on new borewells by farmers (Kiran Patil, Chandrakanth, Manjunath, 2019). The cost of groundwater forms around 15 percent to 30 percent of the cost of cultivation of crops (Kiran Patil, 2014). Thus, MCPD discounts the cost of water used in agriculture, assuming that water is available at zero or low cost which is misleading farmers and policy makers to advocate MCPD as the criterion to increase efficiency.

MCPD treats water as free resource

As MCPD strategy considers the cost of water as low or zero, it may largely be applicable to surface water irrigation from reservoirs and dams with their long life, the fixed and variable cost of water is modest. However, in the case of groundwater irrigation, farmers have to invest on irrigation borewell/s on their farm, face the risk of initial / premature failure of borewell/s, bear with increasing negative externalities due to cumulative interference of irrigation wells in addition to market risks of not realizing higher proportion of consumer price as well as non remunerative market prices. In this article the critical question of whether the strategy of MCPD in groundwater irrigation or the strategy of maximizing net returns per rupee cost of water resource, fetches higher returns to farmers is addressed to decide whether MCPD is a myth or a reality.

II. Agricultural Water Productivity

The agricultural water productivity in this study is measured by MCPD and MNPW as under:

More Crop Per Drop (MCPD)

Following the strategy of MCPD, is to cultivate crops which maximize the crop output (in Kgs) per cubic meter of water akin to maximizing agronomic water productivity. Accordingly,

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

Maximizing net returns per Rupee of Water (MNPW)

Following the MNPW strategy is to cultivate crops which fetch the highest net return per rupee of water cost, akin to the point of Marginal Returns equal Marginal Cost). Accordingly.

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

II (1) Categorization of crops

Based on the water use intensity in cultivation and value of crops, in this study, two types of crops are categorised as under:

1) Low Water Intensive - High Value Crops (LWI-HVC): are all those crops cultivated using less than 10 acre inches (or ha cms) per acre fetching a net return per rupee of expenditure of more than a Rupee
2) High Water Intensive – Low Value Crops (HWI-LVC) - are all those crops cultivated using more than 10-acre inches (or ha cms) per acre fetching a net return per rupee of expenditure of less than a Rupee.

III. India's green revolution is groundwater over exploitation revolution

India's green revolution has also been termed as India's groundwater overexploitation revolution (Chandrakanth, 2021), as the dependence on groundwater has increased by leaps and bounds during and post green revolution. Currently, more than 70% of irrigation in India is from groundwater, and the resource is becoming increasingly expensive over time. NASA highlights groundwater depletion in Punjab, Haryana and Rajasthan as groundwater is disappearing fast from the world and India is among the worst hit, as shown by 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 economically wise in comparison to maximizing profit per rupee of water.

III (1). India is the largest pumper of groundwater in the world

With the largest area under groundwater irrigation, India ranks the first in the world (39 million ha) followed by the US (23 Ml ha), China (19 Ml ha). India tops in the number of irrigation wells in the world (27 million) pumping twice that of the US, or 6 times that of Europe (Chandrakanth, 2015). Irrespective of the cost of extraction of groundwater skyrocketing, more crop per drop has been an advocacy for two decades even though it satisfies an agronomic criterion, acceptable if the groundwater were to be totally free (Giordano et al, 1999).

IV. Sampling framework

In order to address the objective of the study three categories of farmers were sampled using random sampling, from among farmers who have adopted drip/sprinkler irrigation from Eastern Dry Agro-climatic Zone of Karnataka, India, characterized by overexploitation of groundwater resource. In order to reflect the different field reality, sample of farmers were drawn from three farm situations: 1. sample of 30 borewell farmers following drip irrigation were selected, from an area which is not under the command area of irrigation tank characterised as Farms without Tank Recharge (WoTR); 2. sample of 30 borewell farmers following drip irrigation were selected from an area which is under the command of irrigation tank were selected, characterised as Farms With Tank Recharge (WTR); 3. sample of 30 borewell farmers following drip irrigation were selected from an area who were sharing groundwater for irrigation among siblings, in order to incorporate the impact of the institution of sharing water characterized as sharing water farmers (SWF). The water sharing in a farm will reduce the number of further borewell drillings since the sibling farmers are not motivated to drill another well as long as they are satisfied with some volume of water adequate for their farming.

V Methodology

This article juxtaposes 'more crop per drop' on maximizing net returns in farming to identify the corresponding crops cultivated using groundwater in hard rock area, where the groundwater recharge is less than 10 percent of the annual rainfall. Karnataka has the largest number of irrigation tanks (numbering around 36,000) in India, underscoring importance accorded to groundwater recharge in a water scarce region. However, the current situation in irrigation tanks is grim due to encroachments and negligence of the tank system due to heavy reliance on groundwater wells, without appreciating that irrigation tanks and groundwater are hydro-geologically interconnected. Nevertheless, the capacity of groundwater wells in the command of irrigation tank will be different from those which have no access to irrigation tanks. As already mentioned, 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. An unique feature of this region is the popularity of drip irrigation due to economic scarcity of groundwater resource. The field data pertaining to crop year 2016-17 were obtained for analysis.

V (1) Costing of groundwater irrigation

Farmers need a thumb rule for choice of crops based on profitability and resource costs. As mentioned earlier, more than 70% of the irrigation is from groundwater in India. Hence it is crucial to cost/value the groundwater resource. In hard rock areas, the life / age of irrigation wells is difficult to generalize for a region. Farmers over time, will 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 shape the economy of groundwater irrigation characterized by both fixed and variable costs.

V (2) Variable cost of groundwater irrigation

Variable cost component of borewell irrigation is due to the negative reciprocal externality which is due to cumulative interference among irrigation borewells. The borewells which used to serve for at least 15 to 25 years during the 1970s are now serving below 5 or 10 years in hard rock areas post 1990. The cost of drilling and casing irrigation well which was conventionally considered as fixed cost is now considered as variable cost as farmer is forced to drill new irrigation well/s due to initial well failure (where well fails to yield any water after drilling), premature well failure (wells which yield water before the Pay Back Period), subsistence life well (well which yield water up to Pay Back Period). The variable cost also includes cost of operation and maintenance of wells, irrigation structures. The electricity cost is included only for those borewells with irrigation pumpset above 10 Horse Power, as those wells below 10 Horse Power do not pay any electricity charges. The increasing probability of initial / premature failure of irrigation borewells in addition to vastly reducing life / age of irrigation borewells in hard rock areas also contribute to variable cost.

V (3) Electricity cost of pumping

In groundwater irrigation, electricity cost of pumping groundwater is considered as variable cost. With electricity provided free of cost to farmers for irrigation for irrigation pumpsets upto 10 Horse Power, marginal cost of pumping is considered zero. As most of the farmers possess irrigation wells with pumpsets of less than 10 Horse Power, the entire pumping cost of electricity is fully subsidized. However, even though the farmers do not pay for pumping costs, they would have incurred cost on drilling and casing on irrigation wells due to initial, premature failures. Therefore, conventionally even though pumping cost is free, farmers are incurring cost on frequent investments on drilling and casing as probability of initial, premature failures has increased over time. Thus, the variable cost of drilling and casing of irrigation wells is amortized by following the standard amortization procedure. What is crucial to note is the number of years over which amortization has to be accounted for and the rate of interest to be considered.

V (4) How borewell failures are incorporated in costing

In the case of initially failed borewells, the amortized cost of drilling is infinity (or not estimable). Thus, investment on drilling and casing by farmers on initially failed wells or initial failures especially for farms which have suffered large number of initial failures, tends to be excluded from analysis. Therefore, while amortizing the cost of drilling and casing in a farm, it is crucial to amortize the investment not over the actual life of wells, but over the average life of irrigation wells on the farm. The average life of borewells is therefore calculated as life or age of each borewell added up, and then divided by the total number of borewells drilled on the farm at the time of field data collection. The life of borewell refers to the numbers of years borewell yielded groundwater and then failed including initially failed wells. The age of borewell refers to the number of years since yielding groundwater. The life of borewell is zero for initially failed borewells, below payback period for prematurely failed borewell, payback period for well which served up to the payback period called subsistence well, and above the payback period for those borewells called economic borewell. The operation and maintenance costs of the borewell are added (unamortized) incurred every year.

The total amortized cost across all wells is divided by the volume of groundwater extracted in the year of collecting (2017) field data, to obtain the variable cost of groundwater per acre inch (or per ha cm). A sustainable interest rate of 2 percent has been considered for amortization as followed by Diwakara and Chandrakanth (2007). As the variable cost of drilling and casing forms a substantial portion of the total cost of groundwater irrigation from borewells, the cost of electricity forming 20% to 25 % of the cost of groundwater is not a windfall gain for farmers in hard rock areas (Chandrakanth and Kirankumar Patil, 2018).

V 4.1 Amortized Cost of Borewell

In order to obtain the groundwater irrigation cost, the investments made on different borewells on the farm have been 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 was 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. In order to bring all the historical costs on par, investments made by farmer in different years, are compounded to the year 2018 for the latest year at a discount rate of two per cent.

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

Step 2: The compounded investment was later 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 as sunken cost once the well fails either initially, or prematurely. Hence, these two costs are separately amortized to obtain the yearly variable cost and fixed cost of irrigation borewell.

Step 3: Amortized cost of borewell (BW) was worked out as under:

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) $\times \frac{(1+i)^{AL}\times 1}{(1+i)^{AL}-1}$ ….. (2)

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) $\times \frac{(1+i)^{10}\times 1}{(1+i)^{10}-1}$ ….. (3)

Amortized cost of conveyance structure (CS) = (Compounded cost of CS) $\times \frac{(1+i)^{10}\times 1}{(1+i)^{10}-1}$ ...(4)

Amortized cost of micro irrigation structure (MIS)

= (Compounded cost of MIS)$\times \frac{(1+i)^{10}\times 1}{(1+i)^{10}-1}$…. (5)

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) 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

Formulae for compounded costs used as follows

Compounded cost of pump set and accessories

= (Historical cost of P and A) × $(1 + i)^{(2018\text{-year of installation of P and A})}$ ..(6)

Compounded cost of CS = (Historical cost of CS) × $(1 + i)^{(2018\text{-year of installation of CS})}$ …(7)

Compounded cost of MIS = (Historical cost of MIS) × $(1 + i)^{(2018\text{-year of installation of MIS})}$..(8)

V (5) 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. The total investment is

amortized at 2 percent as mentioned earlier 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 VC + amortized FC

Cost of irrigation per acre-inch = (Total annual cost of irrigation) / (volume of water used for the crop in acre inches of GW used) …. (9)

Groundwater use measurement in micro irrigation system

The details of direct estimation of water used through drip irrigation are given below.
The volume of groundwater used for irrigation in each crop (acre inches) in Drip irrigation = {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.

V (6) Externality cost

In hard rock areas, each one's extraction 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. Over time, all 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) which is used in this study.

<u>Accordingly the empirical measurement of externality per borewell is quantified as</u>:

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. Here, the Amortized per functioning well = Total amortized cost divided by the number of functioning wells on the farm; Amortized cost per well = Total amortized cost divided by all the wells on the farm.

Therefore, if there are no failed wells (ie if there are no initial failures, premature failures on the farm), then all wells are functioning and there is no externality. If there are failed wells, then the hypothesis is that the failed wells (or any well failure/s) 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 which indicates the presence of externality.

V (6) Borewell failure and economic life

As mentioned earlier, initial failure of borewell refers to a borewell which did 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 for 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 payback period is obtained by dividing the total investment on (drilling, casing, irrigation pump set, conveyance structure, storage structure, drip/sprinkler structure, recharge structure, electrification charges of) all borewells by the annual net returns obtained per farm and this indicates the number of years required for the irrigation investment to pay for itself. PBP indicates the period within which borewell recovered the investment made from the net returns realized.

V (7) Cost of cultivation

The cost of cultivation is obtained as the sum of cost of human labour, bullock labour, machine hours, seeds, fertilizers, manures and application cost, plant protection measures, bagging, and transporting, interest on working capital at seven per cent, risk premium at two per cent and management cost at five 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.

V (8) Gross Return (GR)

GR is the value of the output and the by product at the prices realized by farmers added up for each crop across all seasons, ie 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.

Gross returns per acre are computed by valuing the total output of each crop at the market price realized. The Gross Return per rupee of expenditure = $\frac{\text{Gross return}}{\text{Total cost}}$

V (9) Net Return (NR)

Net returns from irrigation are equal to Gross Returns (GR) from gross irrigated area (GIA) 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 total cost 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

VI Results

The Low water intensive high value crops (LWI-HVC) in the study area identified were those utilizing around 9.4 acre inches of water per acre yielding a net return per rupee of total cost upto Rs. 1.5. These crops are Ridge Gourd, Ash gourd Carrot, Beans, Brinjal, Cucumber, Onion, Red gram vegetable, Field bean, Lab lab bean, Chilli, Green leafy vegetables - Palak, Amaranthus, Dill Sabbasige, Coriander; flowers- Chrysanthemum, Marigold and the perennial Mulberry. The High water intensive low value crops (HWI-LVC) are those utilizing around 16.23 acre inches of water per acre yielding a net return per rupee of total cost of around Re. 0.68. These crops are Capsicum, Knol Khol, Cabbage, Potato, Tomato, Rose, Ginger, Grapes (Table 1, Pics 1, 2, 3).

Table 1: Crop categories based on water intensity and net returns realized

Crop classification	Crops	Water use per acre in drip irrigation (acre inches)	Net returns per rupee of total cost
Low water intensive high value crop (LWI-HVC)	Mulberry, Ridge Gourd, Ash gourd, Marigold, Carrot, Chrysanthemum, Palak, Beans, Brinjal, Cucumber, Onion, Coriander, Red Gram Vegetable, Field Bean, Lab lab Bean, Chilli, Amaranthus, Dill, Sabbasige	9.40	1:1.50
High water intensive low value crop (HWI-LVC)	Capsicum, Knol Khol, Cabbage, Potato, Tomato, Rose, Ginger, Grapes	16.23	1:0.68

Source: Anitha (2020)

Pic 1: Chrysanthemum in WoTR, G. Hosahalli,

Pic 2 : Mulberry in SWF, Chowdasandra.

Source: Anitha (2020)

Pic 3: Tomato in WoTR, Hebbari, Source: Anitha (2020)

VI (1) Comparable holding size

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 %, 60 % and 56 % of the total in each category (i.e WoTR, WTR and SWF) of sample farmers. Therefore, among borewell irrigated farmers, small and marginal farmers dominated which showed that investment in borewell irrigation attracted them despite the uncertain nature of striking groundwater as indicated by the low probability of well success. Thus results of the study pertaining to access to irrigation did not indicate appreciable inequality across the three categories of farmers using drip irrigation (Table 2). The technology of drip irrigation thus enabled marginal and small farmers to have access to irrigation despite high investments in realizing remunerative returns. The average net irrigated area per farm ranged from 2.73 acres to 3.41 acres while the average gross irrigated area per farm ranged from 5.33 to 5.98 acres per farm. The gross irrigated area formed 71 %, 67% and 63 % of the gross cultivated area across the three categories. Thus, the technology of drip irrigation enabled farmers to irrigate at least 60 % of their gross cultivated area. This is impressive considering that the net irrigated area forms around 50 % of the land holding.

Table 2: Land holding, area irrigated and cultivated by sample farmers (area in acres)

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

Note: Figures in the parentheses indicate per cent to total.
WTR = with tank recharge, WoTR = without tank recharge, SWR =Sharing water farmers; Source: Anitha (2020)

VI (2) Crop economics including cost of irrigation

Inclusion of cost of irrigation water is a crucial aspect in irrigation economics since conventionally land, labour, capital and management were the only considered / recognized 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 (Table 3) indicate that in 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).

Table 3: Cropped area, net returns across sample farms in Karnataka

Particulars	WoTR	WTR	SWF
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)			

Note: 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 % to total; Source: Anitha (2020)

In the WTR farms, about 40 per cent of the gross cultivated area were allocated to LWI-HVC realizing 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. The SWF who shares groundwater with their siblings allocated 34 % of the area for LWI-HVC (flowers, green leafy vegetables) earning net return of Rs.27612 per acre. The lowest area was allocated tom 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 got reduced by 56 % in WoTR farms, by 48 % in WTR farms and by 58 % in SWFs. In the case of HWI-LVC, with the inclusion of cost of groundwater irrigation, the net returns got reduced by 72 % in WoTR farms, by 76 % in WTR farms, and by 69% in Shared well farms. This shows that net returns are over estimated to the tune of at least 50 % to 70 % 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 extraction and use of groundwater on their farms (Table 3).

VI (3) Should farmers grow 'More crop per drop' or maximize net returns?

The differences between the two strategies MCDP or MNPW are reflected in crop choice. If farmers follow the strategy of More crop per drop (MCPD), then they need to cultivate Papaya which ranks the first producing 14.12 quintals per cubic meter of groundwater followed by Palak (13.5), Ash gourd (11.39), Brinjal (9.26), Mulberry (7.14) from among LWI-HWC realizing net returns per acre ranging from Rs. 27612 per acre to Rs. 40517, and Cabbage (11.99 quintals), Tomato (10.02), Potato (8.63), Knol Khol (5) from among HWI-LVC (Table 4). On the other hand, if farmers follow the strategy of maximizing net returns per Rupee of total expenditure (MNPW) on all inputs including groundwater (equivalent to BC Ratio), then they need to cultivate Marigold (Rs. 1.89) followed by Mulberry (Rs. 1.63), Chrysanthemum (1.3), Palak (1.21), Papaya (1.1) from among LWI-HVC, and Capsicum (0.35), Cabbage (0.15), Tomato (0.13), Rose (0.1), Ginger (0.1), Grapes (0.1) from among HWI-LVC (Table 4). Therefore, since groundwater is scarce, groundwater is an economic resource and hence farmers using groundwater irrigation should follow the principles of natural resource economics and choose the strategy of cultivating MNPW crops and not choose the agronomic strategy of maximizing crop production by following MCPD.

The columns 3 and 4 in Table 4 provide the crucial information on crop wise production in Kgs per M^3 of groundwater and net returns per Rupee of total expenditure including the crucial cost of groundwater resource. Considering the wide range of crops among LWI-HVC, papaya ranks first yielding 14.12 kgs per M^3 and Chrysanthemum the least yielding 2.55 kgs per M^3. However considering the same range of crops in net returns per Rupee, Marigold ranks the first fetching Rs. 1.89 net returns per rupee of cost, and red gram and chilli the least fetching net return of Re. 0.1 per rupee of cost. This shows that farmers should be cautions in choosing the right strategy in production, especially since they are investing on groundwater borewells, even though electricity for pumping groundwater is offered free.

Therefore considering that electricity offered for pumping groundwater is a windfall gain for farmers as it is a full subsidy, and if farmers continue to use the strategy of MCPD, they stand to lose heavily as under. Considering the top ranking crop papaya under MCPD which fetches net return of Rs. 1.10 and the top ranking crop Marigold under MNPW, which fetches net return of Rs. 1.89, by cultivating papaya under MCPD strategy, farmers are not only losing net return to the tune of 42 percent but also extracting higher groundwater of 12.68 acre inches per acre for Papaya while they would have extracted only 9.64 acre inches for Marigold, thereby extracting 24 percent higher groundwater volume in cultivating Papaya.

Similarly in the case of High water and low value crops, by following MCPD, farmers would have cultivated top ranking cabbage which fetches 11.99 kgs per M^3 but which fetched only Re 0.15 net return per rupee of expenditure, sacrificing the top ranking crop capsicum fetching the highest net return per rupee of expenditure of Re 0.35 per rupee of expenditure even though it produced only 4.89 kgs per M^3 of water. In the process, by following MCPD strategy, farmers lost net return to the tune of 57%. Therefore it is apparent that farmers should follow MNPW strategy and not MCPD as detailed in Table 4.

Table 4: Comparison of MCPD and MNPW Crops in Karnataka.

Crops (1)	Groundwater used to cultivate one acre of the crop (in M^3) (2)	More Crop Per Drop criterion (Kgs per M^3 of groundwater) MCPD (3)	Maximum Net returns including water cost Per Rupee of total expenditure (Ratio) MNPW (4)
Low water intensive, high valued crops			
Marigold	990.90	6.57	1.89
Mulberry	1737.15	7.14	1.63
Chrysanthemum	1748.46	2.55	1.30
Palak	503.67	13.50	1.21
Papaya	1303.38	14.12	1.10
Coriander	553.01	6.37	1.05
Amaranthus	493.39	6.89	0.80
Dill sabbasige	528.34	6.87	0.71
Carrot	893.25	9.36	0.65
Ash gourd	922.03	11.39	0.57
Ridge gourd	1193.40	4.58	0.49
Beans	946.70	5.70	0.43
Beetroot	1106.02	7.46	0.41
Dolichos lab	1071.07	3.87	0.39
Brinjal	768.87	9.26	0.37
Onion	972.39	5.96	0.34
Cucumber	902.50	5.47	0.22
Field bean	754.48	3.50	0.19
Red gram	684.58	3.59	0.10
Chilli	1253.01	5.15	0.10
High water intensive, low valued crops			
Capsicum	1329.07	4.89	0.35
Cabbage	1001.17	11.99	0.15
Tomato	1377.39	10.02	0.13
Rose	3210.13	1.45	0.10
Ginger	2306.61	1.91	0.10
Grapes	1844.05	4.66	0.10
Potato	1112.19	8.63	0.07
Knol Khol	1168.72	5.00	0.02

Source: Anitha (2020)

VI (4) 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 cent to 70 per cent in different groundwater irrigated crops, since farmers are not accounting for the cost of groundwater irrigation in their estimation of cost of cultivation**. This analysis reflects that farmers need to properly account for cost of groundwater irrigation and accordingly take measures towards sustainable use of groundwater on their farms (Tables 5a, 5b, 6).

VI (5) 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%) followed by labour cost of Rs.13000 (18%) and marketing cost of Rs.10000 per acre (13%). 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 substantial expenditure 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 (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 & 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		fertilizer cost	PPC
	Qty	Rs	Qty	Rs	Qty	Rs	Qty	Rs	Qty	Rs	Rs	Rs
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
	Rs	Vol	VC in Rs	FC in Rs	Rs	Quintal	Rs	Rs	Rs	Rs
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 sabbasige	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

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 ; Source: Anitha (2020)

Table 5 (b): Cost of cultivation per acre for LWI-HVC in Karnataka (continued)

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
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
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
Chili	9014	0	12.19	32913	7741	79433	64.5	1245	80302	870	41524

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; Source: Anitha (2020)

VI (6) Cost of cultivation of HWI-LVC

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. 2,32,000 for Rose. The cost of cultivation of HWI-LVC is higher than the LWI HVC with higher consumptive use of groundwater per acre with lower net return per rupee of expenditure. Considering 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. 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). WoTR farms allocating substantial area for HWI-LVC crops to the tune of 38 per cent are leading towards unsustainable water use. The WTR farms allocated 28 per cent and SWF allocated 27 per cent of the 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. Farmers cultivating HWI-LVC realized the highest net returns per acre inch of groundwater from Capsicum (Rs.3689/ acre inch) followed by Tomato (Rs. 1715/acre inch), Cabbage (Rs. 1563/acre inch), Grapes (Rs. 1074/ acre inch), Ginger beans (Rs.1000/ acre inch), Potato (Rs.813/ acre inch), and Rose (Rs.752 /acre inch).

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
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
	Rs	Rs	Volume in acre inches	VC in Rs	FC in Rs	Rs	In Quintal	Rs	Rs	Rs	Rs
Rose	15250	0	31.23	84321	19831	232243	46.5	5500	255750	23507	127659
Ginger	56150	0	22.44	60588	14249	228368	44	5700	250800	22432	97269
Grapes	28670	0	17.94	48438	11392	199180	86	2540	218440	19260	79090
Cabbage	18000	0	9.74	26298	6185	104775	120	1000	120000	15225	47708
Potato	18935	0	10.82	29214	6871	120798	96	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	2845	184925	47701	90822
Tomato	24683	13550	13.4	36180	8509	182221	138	1487	205206	22985	67674

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; Source: Anitha (2020)

VII. Sources of income

Considering the different sources of income (Table 7) for all sample farmers pooled, around 68 percent of the net returns are generated from irrigation, which includes 31% of net returns from irrigated seasonal crops such as vegetables, flowers, 31% from sericulture (including mulberry) and 6% of the net returns is from dairy. About 32% of the net returns are from rainfed crops which includes 2% of the net returns from Ragi and Pigeon Pea and 30% of the net returns from rainfed Mango crop. Therefore Eastern dry zone historically considered as land of silk and milk has diversified towards vegetables, flowers and fruits zone of Karnataka as they are contributing substantially for total returns. The relative economics of diverse crops such as fruits, vegetables, flowers supported by market demand from the Metropolitan cities of Bengaluru and Chennai, the cultivation of vegetables, fruits and flowers is contributing to 50 % of the gross income of farmers.

The net returns per acre realized by sample farmers are Rs.1.13 lakhs with a net return per capita of Rs. 83000. With the gross returns forming around Rs.15 lakhs per farm and cost per farm around Rs. 10 lakhs per farm per year, the net return is around Rs. 5 lakhs per farm, or Rs. 1.13 lakhs per acre. The cost of cultivation inclusive of water cost accounted for around 65 % or 2/3rds of the gross returns and net returns form 1/3rd. This is a substantial investment and contribution of groundwater irrigation hitherto not valued since groundwater irrigation cost was considered largely as fixed cost.

Table 7: Sources of returns of farmers (n=90)

Sources	Returns per acre or per animal or per DFL (Range)	Gross Returns per farm (Rs)	Cost per farm (Rs)	Net Returns per farm (Rs)	Gross Return per acre /animal/100 DFL(Rs)	Net Return per acre /animal/100 DFL(Rs)	Gross return per capita (Rs)	Net return per capita (Rs)
Rainfed seasonal crops (Ex. Ragi, Tur)	2 (0.5-8)	43257(3)	30912(3)	12345(2)	20168(6)	5153(5)	6968(3)	1999(2)
Rainfed perennial (Ex. Mango)	5.5 (0.5-20)	320919(21)	166180(17)	154742(30)	59433(17)	28656(25)	53486(22)	25790(31)
Irrigated seasonal (Ex: vegetables, flowers)	4.5 (0.5-15)	525527(35)	367817(37)	157710(31)	111101(32)	30917(27)	84168(35)	25194(30)
Irrigated perennial (Ex: Mulberry)	2 (0.5-14)	207320(14)	150610(15)	56709(11)	99672(29)	30057(26)	32755(14)	8864(11)
Dairy	6 (1-30)	131918(9)	98890(10)	32576(6)	31046(9)	8612(8)	20343(8)	5072(6)
Sericulture (only from cocoon production)	1184 (600-2500)	278010(18)	175636(18)	102375(20)	26469(8)	10054(9)	43688(18)	16134(19)
Total		1506952	990046	516457	347888	113449	241408	83053

Note: Figures in parentheses (3^{rd} column onwards) indicate percentage to total; All the 90 sample farmers considered for income source,

Source: Anitha (2020)

VIII. Conclusions

Agricultural water management has been addressing the objectives of increasing farm output, savings in irrigation water, increasing farm incomes, reducing poverty and inequity. Agricultural water productivity traditionally implied "More crop per drop, (MCDP)" but the extent to which this strategy can reflect the scarcity value of groundwater resource is questionable. The MCDP strategy to enhance net farm incomes is plausible only if the water resource is free of cost. However in India, as 70% of irrigation is from groundwater resource and as more than 75% of the investment on groundwater resource is incurred by farmers, due to increasing probability of well failure and associated reciprocal negative externalities, it is crucial to include cost of groundwater in crop economics. This study examines the response of crops to scarcity value of groundwater by comparing the strategy of 'more crop per drop' with strategy of 'maximizing net returns per rupee of total expenditure including cost of groundwater' (MNPW). The choice of crops in both the criteria differs widely since cost of groundwater was included in the cost of cultivation of crops.

The cost of groundwater irrigation including the fixed cost and variable cost components worked out for each of the 35 diverse crops cultivated by farmers to sensitize regarding the right strategy to use in farming reflects interesting results. If the farmers choose to the strategy to maximize their net returns per Rupee of total expenditure (MNPW) (equivalent to BC Ratio), then they need to cultivate Marigold (Rs.1.89) followed by Mulberry (Rs.1.63), Chrysanthemum (1.30), Palak (1.21), Papaya (1.10) from among low water intensive, high value crops; and crops such as Capsicum (0.35), Cabbage (0.15), Tomato (0.13), Rose (0.1), Ginger (0.1), Grapes (0.1) from among high water intensive, low value crops.

However, if the farmers choose MCPD strategy, then they need to cultivate Papaya which ranks the first producing 14.12 quintals 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 quintals), Tomato (10.02), Potato (8.63), Knol Khol (5) from among high water intensive, low value crops. Since scarcity of groundwater is imminent, 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 consider the cost the groundwater irrigation, but merely maximizes output rather than net returns to farmers.

Thus, More Crop Per Drop is a myth and does not fetch maximum net returns to farmers, but only maximizes the physical output of crops per unit volume of water. However, maximizing net returns per rupee of expenditure includes the cost of groundwater resource used for irrigation, offers an entirely different array of crops such as flowers and vegetables which maximizes net returns per rupee of expenditure and benefits the farmers who have invested on precious groundwater immensely. The farmers have to be therefore advised to choose the Maximizing net returns strategy rather than More Crop Per Drop, as More Crop Per Drop fetches lower net returns to farmers compared with the strategy of maximizing net returns per rupee of expenditure which also includes groundwater cost.

Annexure:1

Acronyms used in the study

AL- Average age or Life of borewell
BW-Borewell
CS-Conveyance Structure
DFL-Disease Free Layings
FYM-Farm yard manure
FC-Fixed Cost
GIA-Gross Irrigated Area
GR-Gross Return
GRACE-Gravity Recovery and Climate Experiment
GW-Groundwater
HWI-LVC-High Water Intensive – Low Value Crops
IWMI-International Water Management Institute
LWI-HVC -Low Water Intensive - High Value Crops
MCPD-More Crop per Drop
MIS-Micro Irrigation Structures
MNPW-Maximizing Net returns Per Rupee of Water
NASA-National Aeronautics and Space Administration
NR-Net returns
PBP-Pay Back Period
P and A - pump sets and accessories
PPC-Plant protection chemicals
SDG -Sustainable Development Goal
SWF-sharing water farmers
TR-Total Returns
VC-Variable cost
Vol=Volume of water in acre inches
WoTR-Farms without Tank Recharge
WTR-Farms with Tank Recharge

Bibliography

Anitha S, 2020, Estimation of reciprocal externality induced by economic scarcity of groundwater irrigation in Karnataka, Ph.D. thesis (Unpub) UAS Bengaluru

Chandrakanth, MG., 2015, Water Resource Economics: Towards a Sustainable Use of Water for Irrigation in India, Springer, New York.

Chandrakanth, M G., and Kirankumar, R. Patil, 2018, Internalization of externalities and costing groundwater for irrigation: evidence from a micro study in Karnataka. Aarthika Charche, FPI Journal of Economics & Governance, **3**(2):29-40 http://www.toenre.com/downloads/2018-mgc-Fiscal-Policy-Institute-Jr-of-Economics-and-Governance-internalization.pdf

Chandrakanth, M G, 2021, Did green revolution in Punjab lead to groundwater over exploitation revolution due to MSP, Economic Times, Feb 27, 2021 (https://timesofindia.indiatimes.com/blogs/economic-policy/did-green-revolution-in-punjab-lead-to-groundwater-over-exploitation-revolution-due-to-msp/)

Diwakara, H and Chandrakanth, MG., 2007, Beating negative externality through groundwater recharge in India: a resource economic analysis, Environment and Development Economics, Cambridge University Press, Vol. 12: 271–296 https://www.toenre.com/downloads/2007_EDE_article_MGC_Diwakara.pdf

Giordano, M. H Turral, SM Scheierling, DO Tréguer and PG McCornick, 1999, Beyond "More Crop per Drop": Evolving Thinking on Agricultural Water Productivity, IWMI,1999 http://www.iwmi.cgiar.org/Publications/IWMI_Research_Reports/PDF/pub169/rr169.pdf

Kiran Patil, 2014, Economics of coping mechanisms in groundwater irrigation: role of markets, technologies and institutions. Unpublished Ph.D. thesis, Department of Agricultural Economics, University of Agricultural Sciences, Bangalore.

Kiran Patil, Chandrakanth, MG, and Manjunatha GR, 2019, Impact of Probability of Well Success on Unit Cost of Irrigation in Karnataka, Indian Journal of Ecology, Vol. 46, No. 4, pp. 835-838

Acknowledgement

I express my deep sense of reverence and gratitude to all the farmer respondents of Eastern Dry Zone for their cooperation in collecting field data related to my study. I thank Smt. Nagarathnamma, Sri Anjanappa, Sri K.V. Narayanaswamy, Sri G.V. Manjunath Reddy, Sri Srinivasa Reddy and Sri Chandrashekhar. who helped to collect field data during my study. I am also thankful to UGC, Government of India for offering me the Rajiv Gandhi National fellowship which enabled me to undertake PhD in the Department of Agricultural Economics, University of Agricultural Sciences, Bengaluru from which this paper has resulted. I express my heartfelt gratitude to my revered teacher, guide and chairman of the Advisory Committee, Dr.M.G.Chandrakanth and the members of advisory committee Dr.N.Nagaraj, Dr.Srikanta Murthy, Dr.B.S.Lalitha for their contributions. I thank Sri B R Narayanaswamy, my husband, my parents Smt. Yashodha and Sri Shreenivasa Naik and my children Master Amitabh and Miss Tanmaye for supporting me in undertaking and completing this study.