

**Pampered Views and Parrot Talks:  
In the Cause of Well Irrigation in India**

M. Dinesh Kumar, A. Narayanamoorthy, MVK Sivamohan and Arun Mudgerikar<sup>1</sup>

<sup>1</sup>Executive Director, Institute for Resource Analysis and Policy Hyderabad, Professor and Head, Centre for Rural Development, Alagappa University, Karaikudi, Tamil Nadu, Principal Consultant, IRAP, and Programme Specialist- Water & Sanitation, UNICEF, respectively.  
Email: dinesh@irapindia.org/dineshcgjar@gmail.com.

**Abstract**

This article reveals some of the fallacies in Indian irrigation. They are: 1] well irrigation is superior to canal irrigation; 2] surface irrigation is becoming increasingly irrelevant in India's irrigation landscape in spite of growing investments, and therefore future investments in irrigation should be diverted for well irrigation; 3] the growth in well irrigation in semi arid regions of India can be sustained by using local runoff for recharging the aquifers; and 4] well irrigation can boost agricultural growth and eradicate poverty in water-abundant eastern India. The article argues that surface irrigation systems have inherent advantages over well irrigation systems such as higher dependability and the ability to effectively address spatial mismatch in resource availability and demand, which means that well irrigation is not a substitute for surface irrigation. Further, sustaining well irrigation in semi arid and arid regions would need "imported surface water" rather than local runoff for recharging.

**Keywords:** fallacies, irrigation, agricultural growth

**1.0 Introduction**

India has world's second largest irrigated area. It is known that major irrigation projects contributed to expanding irrigated area in the country over the years. A few scholars have recently documented the larger socio-economic (Bhalla and Mukherjee, 2001) and welfare impacts (Perry, 2001; Shah and Kumar, 2008) of large surface irrigation projects. Private well irrigation system in the last three decades witnessed rapid growth surpassing flow irrigation in its contribution to the net irrigated area (Debroy and Shah, 2003; Kumar, 2007). This was because of massive rural electrification, heavy electricity subsidies and institutional financing for pump sets (Kumar, 2007).

In recent years, a myopic view favouring only private well irrigation in preference to canal irrigation is emerging among a few irrigation scholars in India (see for instance IWMI, 2007; Shah, 2009). This distorted thinking of considering one system superior to the other came because of a poor understanding of determinants of irrigation growth; the fundamental difference between well and surface irrigation; and the basic concepts in hydrology and water management. This has led to several fallacies in the irrigation sector. They are five of them. 1. Future growth in India's irrigation would come from groundwater (Amarasinghe *et al.*, 2008). 2. Well irrigation will have a big role in future agricultural growth and rural poverty alleviation in water abundant regions of eastern India (IWMI, 2007; Mukherjee, 2003; Shah, 2001). 3. Surface irrigation systems are highly inefficient. 4. Of late, returns on investments in surface irrigation systems have become negative. 5. Local water harvesting and recharge can help sustain well irrigation in semi arid and arid regions (Shah *et al.*, 2003; Shah, 2009).

The key questions being investigated in this paper are: 1] can well irrigation alone sustain expansion in India's irrigated area or in India's water resource-water demand scenario, is canal irrigation substitutable by well irrigation? 2] Is surface irrigation really inefficient? 3] Does the declining area under canal irrigation mean negative returns on investments in surface irrigation systems? 4] Can local rainwater harvesting and recharge arrest groundwater depletion and sustain well irrigation economy? and 5] Can well irrigation boost agricultural growth and alleviate rural poverty in water abundant east India?

## 2.0 Analyses, Data Type and Sources

The sets of analysis used in the paper to address the research questions are: per capita groundwater withdrawal in different states ( $\text{m}^3/\text{capita}/\text{annum}$ ); intensity of groundwater use in different states of India ( $\text{m}^3/\text{sq. m}$  of cultivated land); per capita arable land in different states ( $\text{ha}/\text{capita}$ ); per capita effective renewable water availability per unit of arable land in selected basins of India ( $\text{m}^3/\text{capita}$  per annum), and per capita agricultural water demand ( $\text{m}^3/\text{capita}/\text{annum}$ ) in these river basins (8 of them).

The secondary data used for the analysis included district-wise utilizable groundwater resources and ground water draft (year 2005); the rate of siltation of major Indian reservoirs; the gross area irrigated by different sources in different states of India (year 2000); cultivable area available in major river basins of India (year 2000); the minor irrigation census data of 2001 for selected Indian states; the utilizable surface water resources of major Indian river basins; the estimates of references evapo-transpiration in upper and lower catchments of these basins estimated using FAO's CROPWAT model. The secondary data were collected from a wide range of sources. They are: the Central Ground Water Board, the premier scientific institution in India concerned with planning and evaluation of groundwater; the Central Water Commission, another scientific institution at the national level dealing with surface water resources; Ministry of Agriculture; and report of the National Commission on Integrated Water Resources Development.

In addition, we have extensively used analysis provided in several published research papers, including those from the authors, and the most recent international literature on the related topics.

## 3.0 Future of India's Irrigation: Canals or Wells?

Surface irrigation systems provide more dependable sources of water than groundwater-based systems in most parts of India. For flow irrigation, there should be a dependable source of water, and a topography permitting flow by gravity to the places of demand. Ideally, the design itself ensures sufficient yield from the catchment to supply water to the command areas for an estimated duty of the design command, or in other words, the design command is adjusted to match the flows available from the catchment. Hence, the design life of the scheme is by far realistic for reliable "dependable yield" estimates, unless major changes occur in the catchment that changes the flow regimes and silt load.

But, in case of groundwater, thousands of farmers dig wells drawing water from the same aquifer. Since they all operate individually, "safe yield" of the aquifer is not reckoned while designing the well. So, the productive life of a well is not in the hands of an individual farmer who owns it, but depends on the characteristics of aquifer, wells and total abstraction. Two third of India's geographical area is underlain by hard rock formations, with poor groundwater potential (GOI, 2005). Most of peninsular and central India and some parts of western India are underlain by hard rock aquifers of basaltic and granitic origin (see Map 1).

Here, the highly weathered zones formations, which yield water, have small vertical extent-up to 30 m. When the regional groundwater level drops below this zone, farmers are forced to dig bore wells tapping the zone with poor weathering. These bore wells have poor yields, unlike the deep tube wells in alluvial areas such as north Gujarat, alluvial Punjab, Uttar Pradesh and Haryana. For instance, analysis of census data provide in Table 1 show that as high as 40 per cent of the 85,601 deep bore wells (that are in use) in AP were not able to utilize their potential due to poor discharge. The figure was nearly 19.1% for Rajasthan, which have semi consolidated and hard rock aquifers. The figure was 59.9 per cent for Maharashtra, which has basalt formations. Therefore, in spite of explosion in well numbers, the well irrigated area has not increased here during the past decade.

Map 1: Major Aquifers of India

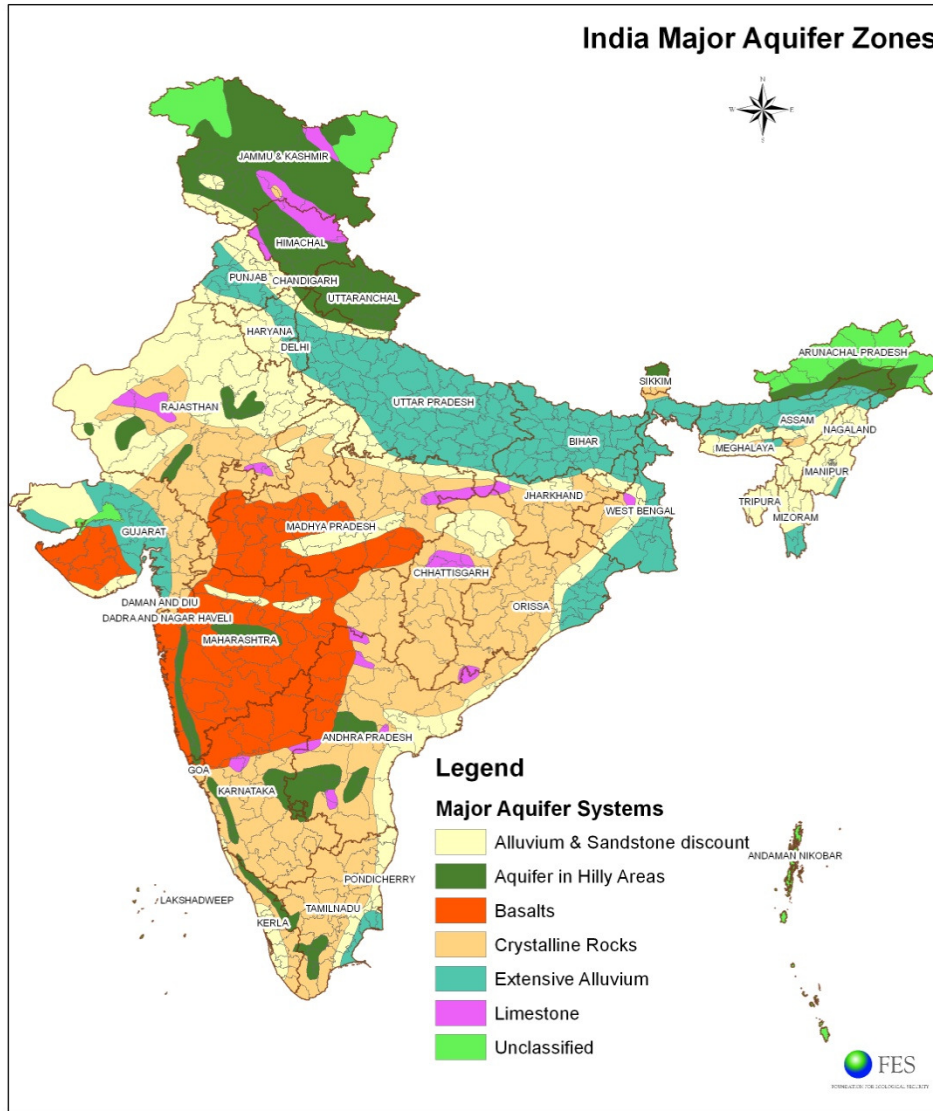


Table 1: Percentage of Dug Wells and Deep Tube Wells Suffering from Poor Discharge in Selected Indian States

Sr. No	Name of the State	No. & Percentage of Wells in Use Which Face Discharge Constraints	
		No. of Deep Tube Wells	% of Deep Tube Wells
1	Andhra Pradesh	34216	40.0
2	Gujarat	20282	24.5
3	Madhya Pradesh	17841	58.5
4	Maharashtra	39958	59.9
5	Orissa	132	7.7
6	Punjab	10	0.10
7	Rajasthan	10010	19.1
8	Tamil Nadu	22838	34.1
9	Uttar Pradesh	3110	9.3

Source: authors' own analysis based on Minor Irrigation Census data 2001

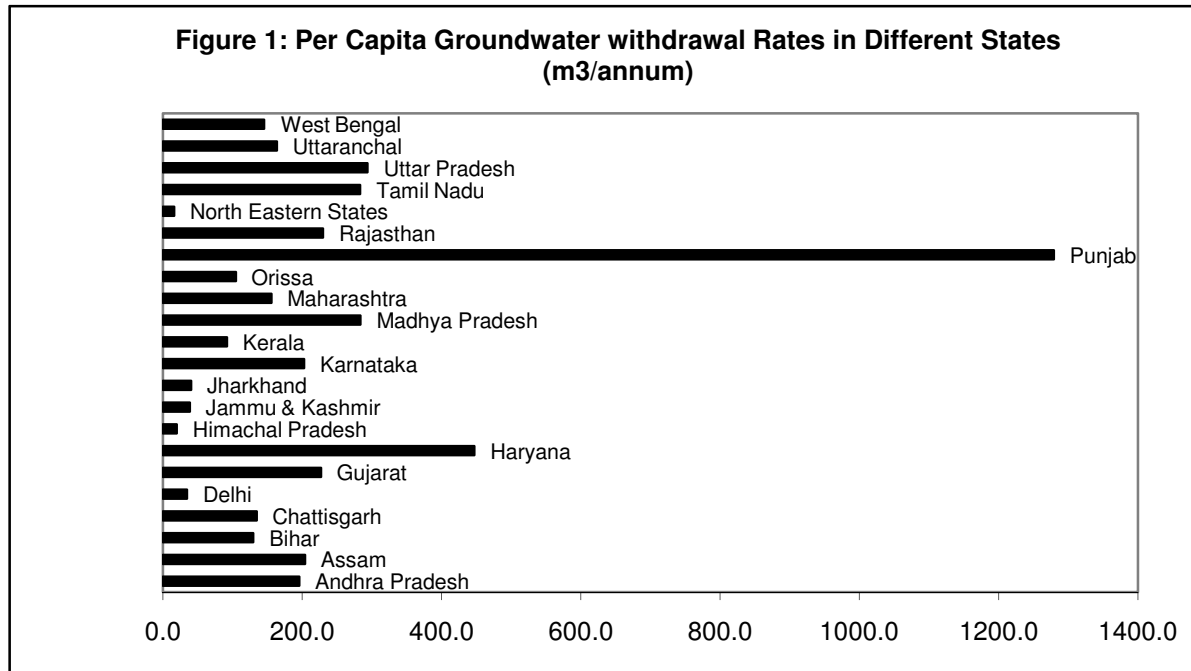
Secondly, growth rate in well irrigation is almost decelerated in most parts of India since nineties. Table 2 shows that most of well irrigation in India is concentrated in the arid and semi arid regions of northern, north-western, western and peninsular India. Amongst this, intensive well irrigation in terms of per capita groundwater withdrawal per annum is highest in some of the northern and north western States, viz., Punjab (1729.9 m<sup>3</sup>/capita/annum), Rajasthan, UP and Haryana and to an extent Gujarat, Tamil Nadu and Andhra Pradesh (Figure 1, Source: Kumar *et al.*, 2008b).

Table 2: Gross Irrigated Area and Well Irrigated Area for Major Indian States

Sr. No	Name of the State	Gross Irrigated Area	Gross groundwater Irrigated Area	Percentage Contribution of Groundwater
1	Andhra Pradesh	5.74	2.45	42.68
2	Bihar	4.55	2.43	53.50
3	Gujarat	3.51	2.81	80.06
4	Haryana	5.22	2.57	49.23
5	Karnataka	3.17	1.19	37.54
6	Madhya Pradesh	4.59	3.10	67.54
7	Maharashtra	3.82	2.63	68.85
8	Orissa	2.39	0.62	25.94
9	Punjab	7.80	5.92	75.90
10	Rajasthan	6.60	4.30	65.15
11	Tamil Nadu	3.50	1.88	53.71
12	Uttar Pradesh	17.67	13.42	75.95
13	West Bengal	3.50	2.13	60.86

Source: Ministry of Agriculture, Government of India, 2000.

Intensive irrigation could sustain for many decades only in a few pockets such as alluvial Punjab and Haryana and UP. This is because these regions are underlain by very good deep alluvial aquifers which have regionally extensive (GOI, 1999; GOI, 2005). These regions are already saturated in terms of irrigated area. Further, expansion in irrigated area is not possible in these areas. Whereas in Rajasthan, Gujarat, Andhra Pradesh and Tamil Nadu, problems of over-exploitation halt further growth in well



irrigation. Most of the untapped groundwater is in eastern Gangetic plains, devoid of sufficient arable land that lies un-watered (Kumar and Singh, 2005; Shah and Kumar, 2008; Kumar *et al.*, 2008b). Peninsular India and central India have a lot of un-irrigated land. Agriculture is prosperous in this part of the country, and demand for water is only going to grow. But, well irrigation is experiencing a “leveling off” and sometimes decline due to “over-exploitation” and monsoon failure.

A recent analysis in the hard rock areas of Narmada river basin in Madhya Pradesh showed that the average area irrigated by a single well has declined over a 25-year period (Table 3 based on Kumar, 2007). Such a phenomenon is occurring due to well-interference, a characteristic feature of hard rock areas, which starts occurring when all the groundwater, that can be tapped, is already tapped. In such situations, an increase in number of wells does not result in increase in total irrigated area (Kumar, 2007). Hence, it is wrong to assume that well irrigation in India could sustain the same pace of growth in coming years.

Table 3: Reduction in Average Command Area of Wells over Time in Selected Districts of Madhya Pradesh

Name of District Falling in Narmada Basin	Average Area Irrigated by a Well in					
	1974-75	1980-81	1985-86	1991-92	1995-96	2000-01
Balaghat	4.50	2.25	2.35	2.57	1.73	1.96
Chhindwara	4.56	2.58	2.26	1.42	1.50	1.75
Shahdol	2.04	0.18	0.50	0.70	0.99	0.47
Jhabua	2.93	1.87	0.89	1.20	1.26	0.57
Betul	6.97	3.37	3.02	1.98	2.06	2.18

Source: Kumar (2007)

The spatial imbalance in resource availability and demand is aggravated by uneven distribution of surface water resources spatially. Nearly 69% of India’s surface water resources are in the GBM (Ganga-Brahmaputra-Meghna) basin (GOI, 1999). In the GBM basins, the water demand in agriculture is far less than the total renewable water resources, which is sum of both renewable surface water and groundwater (Table 4), whereas in the five basins of south, western and Central India, the water demand for agriculture alone exceeds the renewable water resources (Table 5).

Table 4: Per capita Renewable Water Resources and Per Capita Water Demand in Agriculture in Three River Basins

Sr. No	Name of the basin	Average Annual Rainfall in the basin		Average Renewable Water Resources (m <sup>3</sup> /capita) <sup>1</sup>	Effective Renewable Water Resource (m <sup>3</sup> /capita) <sup>2</sup>	Mean Annual Reference Evapo-transpiration (mm)		Water Demand for Agriculture (m <sup>3</sup> /capita/annum)
		Upper	Lower			Upper	Lower	
1	Ganga	1675	1449	1081.56	1476.60	710.00	1397.00	1387.66
2	Brahma putra			1649.86	2288.10	1064.00	1205.00	2413.62
3	Meghna							

Source: authors’ own estimates based on ET<sub>0</sub> values estimated from FAO CROPWAT, and population and renewable water availability figure obtained from GOI, 1999.

<sup>1</sup>The average annual water resources was estimated by taking the sum of annual utilizable runoff (GOI, 1999: Table 3.6) and the dynamic groundwater resources from natural recharge in these basins (GOI, 1999: Table 3.9) and dividing by the geographical area of the basin.

<sup>2</sup>The effective renewable water resources were estimated by dividing the average renewable water resources for the basin by the fraction of total cultivated land to the total basin drainage area. The basin-wise total cultivated land considered was for the year 1993-94 (GOI, 1999: Annexure 3.2, pp 422).

Notes: i] In estimating the renewable water resources, only the utilizable water resources are considered. The remaining part is un-utilizable because of the topography existing in these basins, and the peak flows. This un-utilized part can be treated as the flows available for ecosystems downstream after diversions.

ii] The net cropped area figures considered for each basin are for 2050, as per the projections provided in the National Commission on Integrated Water Resources Development (GOI, 1999): Annexure 3.2, pp 422. They are higher than the actual cultivated area in these basins at present. This leaves the chances of under-estimation of water demand for agriculture in our methodology

iii] The total static groundwater resources in the two basins was estimated to be 21,774 and 28,841 MCM, respectively (source: GOI, 1999: Table 3.11: pp 46).

Table 5: Average Reference Evapo-transpiration Against Mean Annual Rainfall in Selected River Basins in Water-Scarce Regions

Sr. No	Name of the Basin	Mean Annual Rainfall (mm)		Average Annual Water Resources (mm)	Effective Annual Water Resource (mm)	Reference Evapo-transpiration (mm)	
		Upper	Lower			Upper	Lower
1	Narmada basin	1352.00	792.00	444.70	937.60	1639.00	2127.00
2	Sabarmati basin	643.00	821.00	222.84	309.61	1263.00	1788.80
3	Cauvery basin	3283.00	1337.00	316.15	682.80	1586.90	1852.90
4	Pennar basin	900.00	567.00	193.90	467.80	1783.00	1888.00
5	Krishna basin	2100.00	1029.00	249.16	489.15	1637.00	1785.90

Sources: Kumar *et al.*, 2008

This imbalance can be effectively addressed only by large surface water projects, and not by groundwater projects (this, however, does not trivialize the role of demand management in regions where demand exceeds supplies). Historically, water was taken from rich upper catchments of river basins, which formed ideal locations for storages (Varghese, 1990). Surface irrigation can expand in future also with investments in large reservoirs and transfer systems that can take water from the abundant regions of the north and east to the parched, but fertile lands in the south, though their economic viability and social costs and benefits will have to be ascertained. But, the same is not true for wells, as engineering feasibility of transferring groundwater in bulk itself is a questionable proposition. The greatest example is the hyper-arid north western Rajasthan. The six districts of this region, which have endogenous surface water, and saline groundwater, are now irrigated by water from Indira Gandhi Canal, which carries water from Sutlej River in the Shivalik hills of Himachal Pradesh in north India. It irrigates a total of 2.035 million ha of land.

#### 4.0 How Far Are Surface Irrigation Systems Inefficient?

Engineering efficiencies in large surface irrigation projects in India are much less than that of well irrigation schemes (GOI, 1999). But, such comparisons are used by some scholars to build the argument that surface irrigation projects are performing very badly, and that the government investment in surface irrigation should be diverted for better management of aquifers. While it goes without saying that management of canal irrigation leaves much to be desired, such arguments are based on obsolete irrigation management concepts, which treated the water diverted from reservoirs in excess of crop water requirement as “waste” (Howell, 2001; Seckler, 1996). But, these comparisons are not reflections of economic efficiency of the entire systems as the wastewater gets re-used in the downstream part of the same system by well irrigators (Chakravorty and Umetsu, 2003).

As Seckler (1996) notes, the fundamental problem with this concept of water use efficiency based on supply is that it considers inefficient both evaporative loss of water and drainage. It is not well informed by the water use hydrology of surface irrigation systems. Most of the seepage and deep percolation from flow irrigation systems replenish groundwater, and is available for reuse by well owners in the command (Allen *et al.*, 1998; Seckler, 1996). This recycling process not only makes many millions

of wells productive, but also saves the scarce energy required to pump groundwater by lowering pumping depths. This is one reason why well irrigation can sustain in many parts of Punjab and Haryana, Mulla Command in Maharashtra, in the Krishna river delta in AP and Mahi and Ukai-Kakrapar command in south Gujarat.

B. D. Dhawan, one of the renowned irrigation economists, looked at the economic returns from surface irrigation systems in his book wherein he examined the merits of he claims and counter-claims about the benefits of big dams. He had highlighted the social benefits generated by large irrigation schemes through the positive externalities such as improvement in well yields, and reducing incidence of well failures and increasing the overall sustainability of well irrigation by citing the example of Mulla command in Maharashtra (see Dhawan, 1990).

The social benefits (positive externalities) these canals generate by protecting groundwater ecosystems are immense (Shah and Kumar, 2008), reduced energy cost for pumping groundwater being one (Vyas, 2001). The likely impact of this on the energy economy of the country will be evident from the fact that electricity subsidy for agriculture in India was to the tune of Rs. 30,462 crore in 2001-02. Most of this goes to subsidizing pump irrigation, to the states having large areas under well irrigation such as Punjab, Gujarat, Haryana, Madhya Pradesh, Maharashtra, Rajasthan, Tamil Nadu, Karnataka and Andhra Pradesh. It is also seen that the subsidy went up in nine years from just Rs. 7335 crore in 1992-93 (source: Planning Commission, 2002).

But, irrigation planners have, by far, nearly failed to capture these social benefits in the cost-benefit calculations (Shah and Kumar, 2008). The recent data from government of Andhra Pradesh shows that the command irrigated regions of the state have the lowest number of groundwater “over-exploited” mandals. The tail end regions of the canals have sufficient number of bore wells, which actually reap the benefit of return flows from canals, and thus have good yields. The large reservoirs had raised cereal production to the tune of 42 million ton in fifty year since Independence. The social benefit this had generated by lowering cereal prices in the country was estimated to be Rs.4300 crore annually (Shah and Kumar, 2008). Added to these are the multiple use benefits that canal water generate such as fish production, water for domestic use and cattle in rural areas.

## **5.0 Groundwater Recharge using Local Runoff: Catching the Crane Using Butter?**

It is often suggested that flows from the small canals (Shah, 2008) or small water harvesting/artificial recharge structure (GOI, 2007; Shah, 2009) should be used for recharging aquifers. This is fallacious as the arid and semi arid regions, where aquifers are depleting (GOI, 2005; Kumar, 2007), have extremely limited surface water (Kumar *et al.*, 2008a). Map 2 shows the over-exploited districts in India (source: GOI, 2005). They are in western and central Rajasthan; almost the entire Punjab; alluvial north Gujarat; and parts of Andhra Pradesh, Madhya Pradesh, Maharashtra and Tamil Nadu. The surface water resources in the basins, where these districts are falling, are extremely limited and are already tapped using large and medium reservoirs (source: GOI, 1999). Hence, the over-exploited regions coincide with the regions of surface water shortage.

Any new interventions to impound water would reduce the d/s flows, creating a situation of “Peter taking Paul’s water”. Such indiscriminate water harvesting is also leading to conflicts between upstream and downstream communities as reported by Ray and Bijarnia (2006) for Alwar in Rajasthan; Kumar *et al.*, 2008a for Saurashtra in Gujarat. Kumar *et al.* (2008a) shows that in semi arid and arid regions water harvesting/recharge not only has poor physical feasibility and economic viability, but has negative impacts on access equity in water (Kumar *et al.*, 2008a).

The idea of dug well recharging is being pushed for the hard rock areas on a false notion that it is a cheap (costing only Rs. 4,000 per well), easy and safe method of groundwater banking, unlike what is being practiced in the United States and Australia (Shah *et al.*, 2009). But, this is far from the truth. Collecting runoff from the lowest points in the farm, channelizing it to the well location, and then filtering it before finally putting in the well could be quite expensive as land leveling and filter box construction would cost high, depending on the farm size and soil type (Farmers in some parts of Gujarat, who have dried up open wells, laughed away this idea as impractical, when it was mooted by two of the contributors of this article). Over and above, spending such large sums no way guarantees environmental safety as the runoff would contain fertilizer and pesticide residues from the field. Further, as Kumar *et al.* (2008a) argued, the central government’s Rs. 1800 crore-scheme to recharge groundwater through 4 million open wells, if implemented, would render many small and large reservoirs unproductive. Hence, well irrigation

in peninsular and western India cannot be sustained unless water is brought from surplus basins in the east and north for recharging the aquifers there.

Bringing water from water-surplus basins to peninsular India would require large head works, huge lifts, long canals, intermediate storage systems, and intricate distribution networks. As we have argued, recharge schemes using local water are economically unviable. The reason is that while the cost per cubic metre of recharge is abnormally high (see Table 6), the returns from irrigated crop production are far less (in the range of Rs. 1 to Rs. 17 /m<sup>3</sup>) as found in a study of irrigation water productivity of various crops in nine agro climatic sub-regions of Narmada river basin in Central India (Kumar *et al.*, 2008a). Need for vast precious land for spreading water for recharge, would make it also socially unviable, while further increasing economic costs.

Table 6: Estimated Unit Cost of Artificial Recharge Structures Built under Pilot Scheme of CGWB

Sr. No	Type of Recharge Structure (Life in years)	Expected Active Life of the System	Estimated Recharge Benefit (TCM)	Capital Cost of the Structure (in Lac Rs.)	Cost of the Structure per m <sup>3</sup> of water (Rs/m <sup>3</sup> )	Annualized Cost* (Rs/m <sup>3</sup> )
1	Percolation Tank	10	2.0-225.0	1.55-71.00	20.0-193.0	2.00-19.30
2	Check Dam	5	1.0-2100.0	1.50-1050.0	73.0-290.0	14.60-58.0
3	Recharge Trench/Shaft/	3	1.0-1550.0	1.00-15.00	2.50-80.0	0.83-26.33
4	Sub-surface Dyke	5	2.0-11.5	7.30-17.70	158-455.0	31.60-91.00

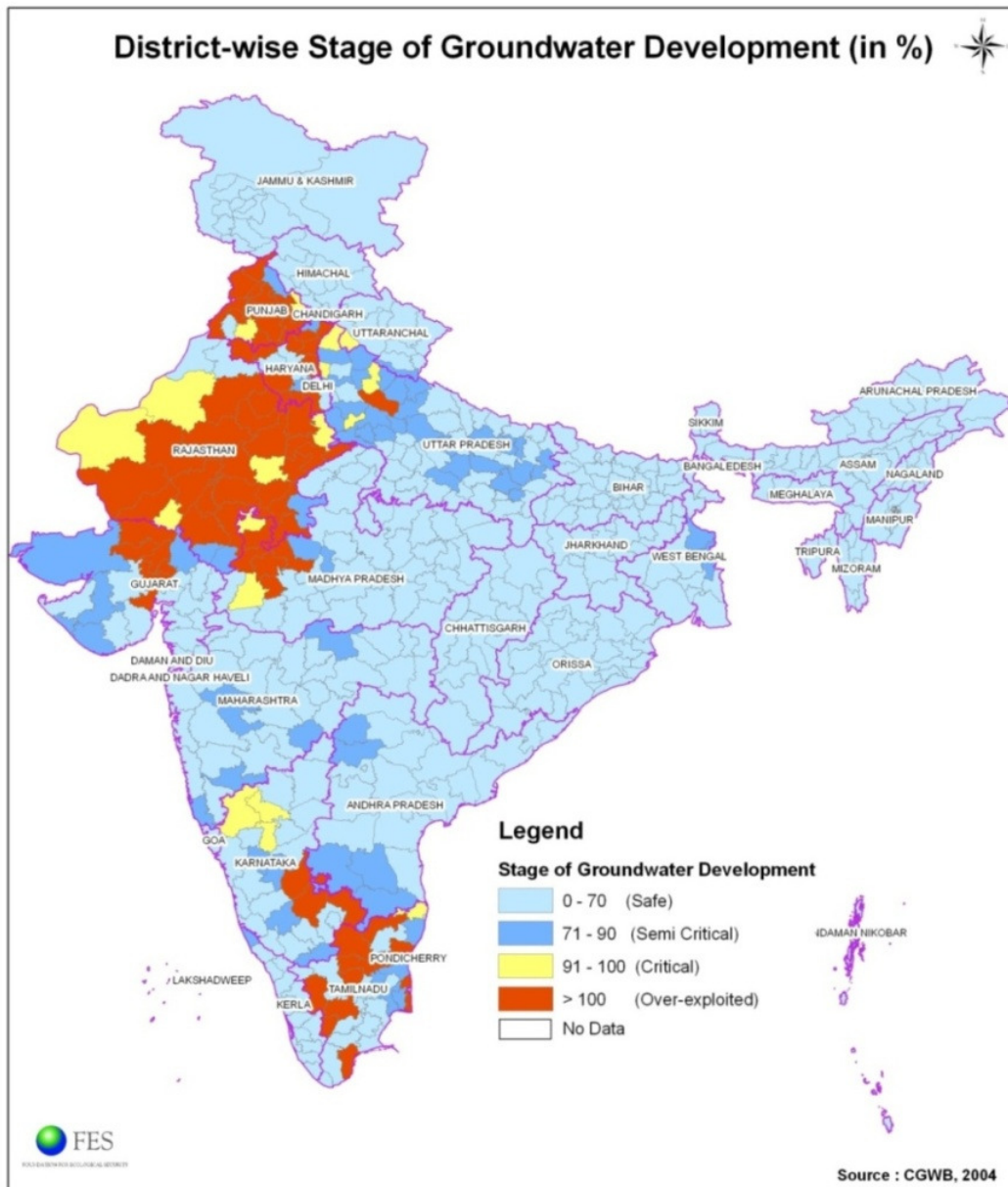
Kumar *et al.*, (2008a) based on GOI, 2007, Table 7: pp14

Since the aquifers in hard rock areas of India have extremely poor storage capacities, efficient recharge would require synchronized operation of recharge systems and irrigation wells. This would call for advanced hydraulic designs, and sophisticated system operation. Therefore such an approach of using imported surface water for recharge would sound like “catching the crane using butter”. The fact that practicing environmentally sound artificial groundwater recharge in these water-scarce hard rock areas is a very expensive affair, requiring application of advanced science, is yet to be appreciated by a section of the water community.

Hence, the best option would be for the farmers to use this expensive canal water for applying to the crops in that season of import (mainly monsoon season), and use the recharge from natural return flows for growing crops in next season. Opportunities for using water from “surplus basins” for recharging depleted aquifers exist at least in some areas. Examples are alluvial north Gujarat and north-central Rajasthan. Ranade and Kumar (2004) has proposed use of surplus water from Sardar Sarovar Narmada reservoir during years of high rainfall for recharging the alluvial aquifers of north Gujarat through the designated command area in that region (Ranade and Kumar, 2004). They proposed the use of existing Narmada Main Canal, and the rivers and ponds of north Gujarat for this, and their analysis showed that it is economically viable. It can protect groundwater ecology by reducing pumping; reduce the revenue losses in the form of electricity subsidy; and increase the flows in rivers that face environmental water scarcity, apart from giving direct income returns from irrigation. But, one cannot agree more on the point raised by Rath (2006) that only crops having very high water use efficiency will have to be promoted in the commands receiving such waters so as to generate sufficient returns from irrigated production. But, this will be possible only if the price of irrigation water is pitched at a level it starts reflecting the scarcity value of the resource.



Map 2: Over-exploited, critical and semi critical districts in India



## 6.0 Is Contribution of Surface Irrigation Declining?

In the year 2000, wells accounted for nearly 61% of India's gross irrigated area (46.41 m. ha), with the rest from canals and tanks (29.34 m. ha) (source: Agricultural Census, GOI, 2000). But to make a choice between surface scheme and groundwater scheme based on crude numbers of "irrigated area by source" is "hydrologically and economically absurd". Which model of irrigation is best suited for the area in future can be judged by the nature of topography, hydrology and aquifer conditions. For instance, in rocky central and peninsular India, only imported surface water can sustain and expand well-irrigation. Indiscriminately embarking on well irrigation would only ruin the rural economy. Farmers in these regions

desperately drill bore holes to tap water with high rates of failure (Kumar and Singh, 2008), and resultant farmer suicides.

At least some scholars have begun to use “declining area under canal irrigation” to build a case for stopping investments in surface irrigation (Shah, 2009; TOI, July 10 & 17, 2008 for Indian irrigation; Mukherjee and Facon, 2009 for Asian irrigation). They seem to argue that the change in cumulative area irrigated by canals is a good indicator of the return on investment in surface irrigation systems. But, this is a clear case of misuse of statistics. Such arguments come from poor understanding of how surface irrigation systems work. This will be revealed if we look at the real factors that influence the irrigation performance of surface systems.

First: as a recent study in Narmada river basin in central India shows, increased pumping of groundwater in upper catchments for agriculture can significantly reduce stream flows in basins where groundwater outflows contribute to surface flows (Kumar *et al.*, 2006), thereby affecting the inflows into reservoirs. In fact, the whole country experienced a quantum jump in the number of agricultural wells during 1970s and 1990s (Debroy and Shah, 2003). In a small watershed called Maheshwaram in Andhra Pradesh with a drainage area of 64 sq. km (6400 ha), during 1975-2002, a total of 707 wells came up, all in the valley portions (source: National Geophysical Research Institute (2002) as cited in Armstrong, 2004). Now, rights to groundwater are not well-defined in India, and landowners enjoy the rights to use the groundwater underlying his/her piece of land (Saleth, 1996). Since agricultural wells are mostly private, *de facto* groundwater is a private property. Therefore, it is beyond the institutional capacity of state irrigation bureaucracies to control such phenomenon occurring in the upper catchments of their reservoirs. Also, as is evident from the earlier discussions and from some studies, small water harvesting systems are adding to the reduction in inflows into reservoirs (Kumar *et al.*, 2008a; Ray and Bijarnia, 2006).

Second: farmers in most surface irrigation commands install diesel pumps to lift water from the canals, and irrigate the fields. Such instances are increasing with pump explosion in rural India. The better control over water delivery, which farmers can secure by doing this, is the reason for their preference for energy-intensive lifting to gravity flow. Another important reason is the illegal water diversion which is rampant in canal irrigation. The pumping devices enable illegal diversion of water for irrigating plots that are otherwise out of command due to topographical constraints. This was found to be rampant in many large irrigation commands. To name a few are Dharoi irrigation command in north Gujarat; Mahi irrigation command in south-central Gujarat; and Mulla-Mutha command in Maharashtra. Such areas get counted as pump irrigated areas in government statistics.

Third: large reservoirs, primarily built for irrigation in this country, are being increasingly used for supplying water to big cities and small towns as recent studies show. A recent analysis involving 301 cities/towns in India shows that with increase in city population, the dependence on surface water resources for water supply increases, with the dependence becoming as high as 91% for larger cities (Figure 3, Source: Mukherjee and Shah, 2008). Many large cities depend almost entirely on surface water imported from large reservoirs. Some examples are Bangalore, Ahmedabad, Chennai, Rajkot and Coimbatore, with contribution ranging from 91 to 100% (ADB, 2007). Many of them used to depend on local tanks and ponds and bore wells in the past for meeting their water needs.

Fourth: farmers in canal command areas, especially at the head reaches, tend to put more area under water intensive crops, ignoring the cropping pattern considered in the design. This is one of the reasons for shrinkage in the irrigated command area.

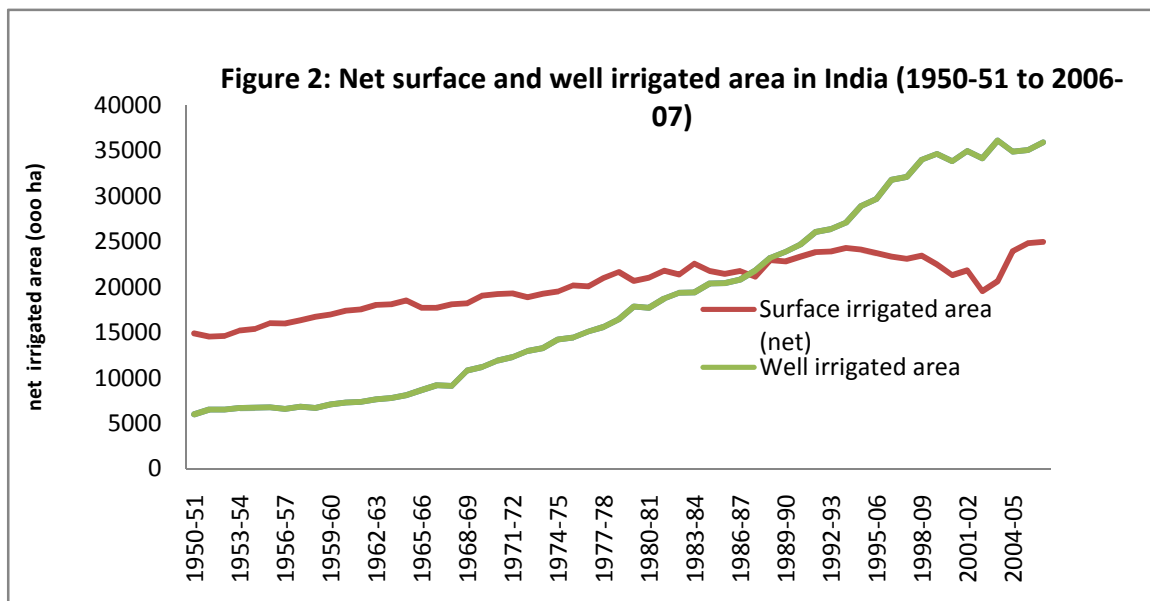
Fifth: water from many large surface irrigation systems in many parts of India are used to feed tanks and ponds in the command area and also along the canal alignment, when the farmers do not need water at the time of its release in canals. This water is subsequently lifted using pumps to irrigate crops when water release from canals stop. This gets counted as area irrigated by tanks/ponds and not as “canal irrigated area”. These tanks/ponds also become ideal for raising fish and prawns as found in the Godavari delta in Andhra Pradesh and Mahi command in Gujarat.

Last, but not the least, reservoirs are experiencing problems of sedimentation causing reduction in their storage capacity and life, though as found world-wide in some cases the rates are higher those used at the time of design (Morris and Fan, 1998). The average annual loss of live storage for 23 large reservoirs in India with a total original live storage of 23,497 MCM (23.497BCM) studied by the Central Water Commission was to the tune of 213 MCM, i.e., an annual reduction of 0.91 per cent. Hence, generally for older reservoirs, the loss of storage would be quite significant. Such annual losses can

sometimes reduce the effect of additions in storage achieved through new reservoir schemes on expanding irrigation.

Therefore, in the natural course, with the passage of time, area under surface irrigation would decline, if nothing is done to revive the live storage of reservoirs. It is also therefore quite obvious that with cumulative investments in surface irrigation systems going up with time, there may not be proportional rise in surface irrigated area. In order to evaluate the performance of surface schemes vis-à-vis return on investment, it is important to look at the performance of individual schemes considering these factors. At least some of these above facts are compelling reasons for fresh thinking on the planning and implementation of irrigation in India. Clearly, the solution does not lie in completely writing off surface systems for wells as the latter ones are not a substitute for the earlier.

While these scholars lament the “dismal” performance of canal irrigation schemes in India, and stress for giving impetus to well irrigation (Mukherjee and Facon, 2009; Shah *et al.*, 2009: page 13), what is more noteworthy is the fact that the area under surface irrigation, which includes canal irrigation, tank irrigation and irrigation through canal & river lifting, has been steadily increasing during the past five and a half decades and peaked in 2006-07, in spite of the myriad of problems discussed above. Though there was a minor short term decline observed during 1993-94 and 2002-03, this decline was due to many factors. Three of them are: lack of adequate investments for new schemes (source: Planning Commission, 2008), droughts and increasing diversion of water from reservoirs to urban areas. Whereas the growth in well irrigation has declined significantly after 2000, with a growth rate of 0.18 m. ha/year against 1.05 m. ha/year observed during 1987-88 and 1999-00, and 0.634 m. ha/year observed during 1967-68 and 1987-88 (see Figure 2).



Sustaining well irrigation growth is a matter of concern, as 15% (839) of the blocks/talukas/ mandals in the country are over-exploited; 4% are critically exploited and 10% (550) are in the semi critical stage (GOI, 2005), and these regions contribute very significantly to India’s well irrigation.

## 7.0 Can Wells become the “Poverty Alleviating Machines”?

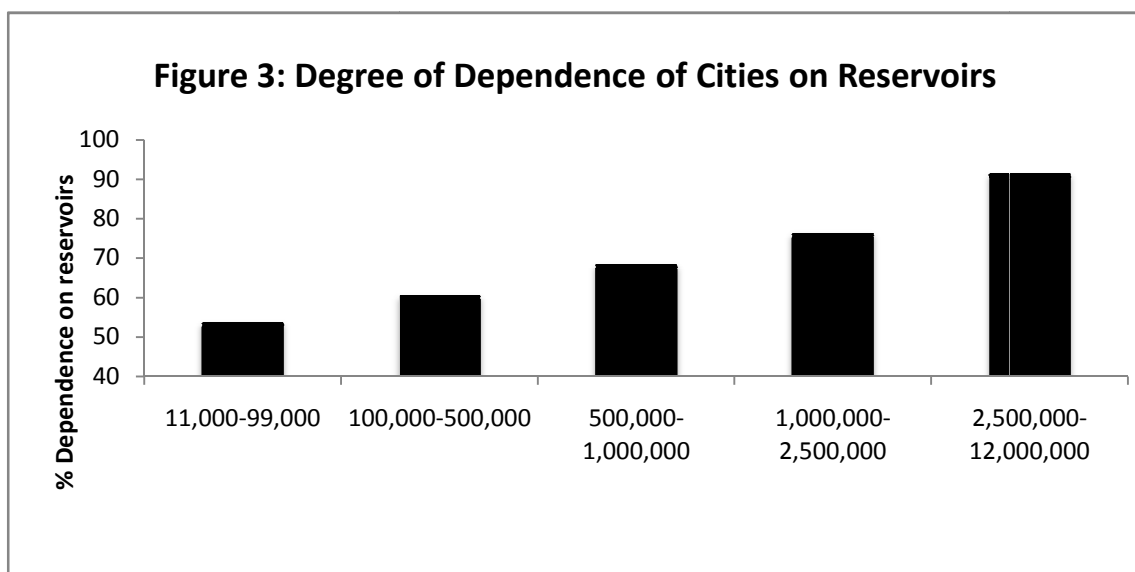
Over the past few decades, well irrigation has been romanticized by some scholars as a poverty alleviating machine (Debroy and Shah, 2003; IWMI, 2007; Llamas, 2002; Mukherjee, 2003). While it is understood and also well documented by many scholars in the past that irrigation has a significant impact on poverty alleviation in rural areas (Bhattarai & Narayanamoorthy, 2003; Hussain and Hanjira, 2003), the over-emphasis on groundwater is somewhat difficult to assimilate. More strikingly, major arguments about the poverty impact of groundwater irrigation are made in the context of eastern India (Shah, 2001;

Mukherjee, 2003; IWMI, 2007). As Mukherjee argues, “in regions of abundant rainfall and good alluvial aquifers, ground water irrigation can be a powerful catalyst in reducing poverty (source: IWMI, 2007).

Eastern India’s potential for triggering country-wide agricultural growth through a boost in well irrigation is also strongly argued (Shah, 2001; Mukherjee, 2003). Poor rural electrification and inadequate incentives for diesel pump dealers were blamed for the poor growth in well irrigation (Shah, 2001). Here, one really wonders about the actual effect of rainfall on irrigation demand. Also, one wonders about the effect of irrigation versus land on economic surplus in areas of high water availability. Marginal returns from irrigation would be higher in areas of high aridity and low moisture availability, and not in humid/sub-humid areas with high moisture availability as shown by an analysis which involved western Punjab and eastern Uttar Pradesh (Kumar *et al.*, 2008c). Eastern India falls in the latter.

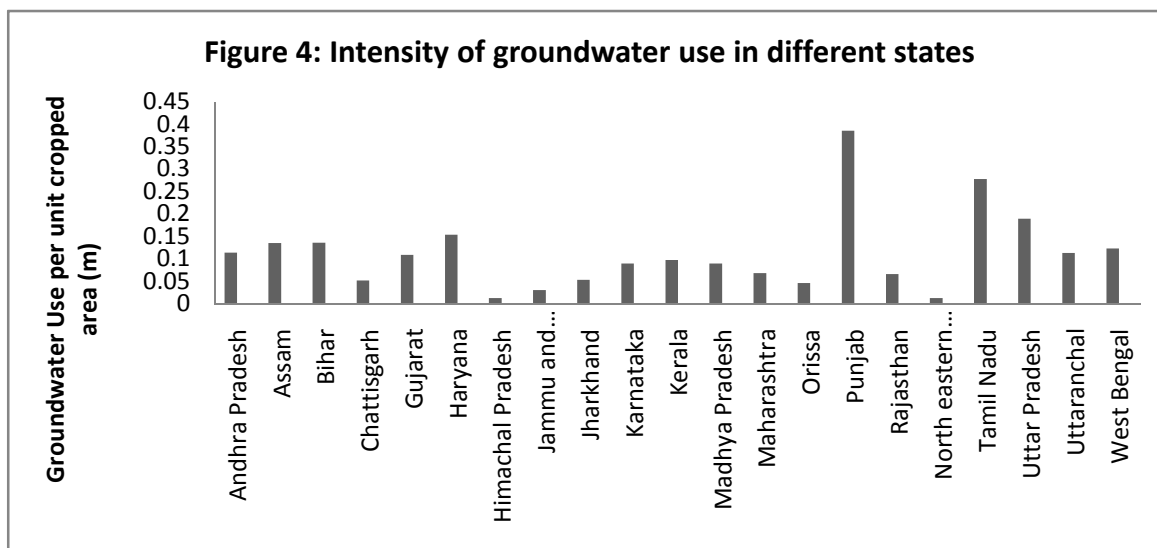
What is surprising is that in the entire policy discourse on the impact of irrigation on agricultural development, the key factor of production, i.e., “land” does not find a place anywhere. In fact, it is simply fallacious that a boom in well irrigation could be created in eastern India through proper rural electrification and energy policies. The reason is the water demand for irrigation is very low in this region.

The maximum water needed for irrigation is a direct function of per capita arable land and reference evapo-transpiration; and inverse function of effective rainfall, provided the socio-economic conditions are favourable. In eastern India, not only that the rainfall is high, but the ET is comparatively lower than western, north western and southern India. The per capita arable land is lower than that of western, peninsular and north-western India (Kumar *et al.*, 2008b). In Bihar, it is one of the lowest in the country with 0.068 ha against 0.17 ha in Punjab, and only 40% of the net sown area remained un-irrigated in 2000 (source: based on Agricultural Census, Ministry of Agriculture, GOI, 2000).



The groundwater use intensity is already quite high in Bihar and other eastern Indian states like Assam and west Bengal (see Figure 4). This is far higher than the groundwater use intensity in Rajasthan and Andhra Pradesh, which are facing severe problems of over-exploitation. That said, already more than 60% of the net sown area in Bihar is irrigated.

Even if we improve the affordability of irrigation water for millions of poor farmers in this region, what we can achieve is very minimal. Unfortunately, such pampered views dominate the water policy debate in India. The huge opportunity cost of delaying the most essential investments in irrigation, in regions where it matters, is by and large ignored. But, much higher growth in agricultural production can be realized through multiple uses of water.



Recent field based research by ICAR (Indian Council of Agricultural Research) shows that well-designed multiple use systems can enhance the productivity of use of both land and water in eastern India remarkably. This involved integrating fisheries, prawn farming and duckery with paddy irrigation using local secondary reservoirs for the water (Sikka, 2009).

## 8.0 Water Quality Aspects

An aspect which is least appreciated by policy makers is the differences in quality of water from aquifers and canals. Canal water, which originates from forested catchments of rivers and glaciers, carries a whole range of micro and macro nutrients. These nutrients get deposited on the agricultural land, and over the years make the land more productive. A recent comparative study of canal irrigation and well irrigation, carried out in Nawah Shehar district of in Punjab showed that the canal irrigated paddy gave higher yield and water productivity than well irrigated fields in spite of lower reliability of supplies. The differential yield came from the better soil nutrient regime in canal-irrigated fields (Trivedi and Singh, 2008). Recent field work carried out in Mahi irrigation command in Anand district of Gujarat showed farmers' preference for canal water for growing crops such as banana, vegetables and paddy, attributed to the better chemical quality of canal water when compared to water from the tube wells (Source: primary data collected by Amit Patel, Research Assistant, IRAP).

Against this, groundwater resources in many semi arid and arid regions have high levels of mineral contaminants. More areas are getting affected by water quality problems over time (Kumar and Shah, 2004; Kumar, 2007). These minerals can increase the soil salinity and some crops won't grow under such saline conditions, particularly when the soil is heavy and rainfall is less. Arsenic present in the groundwater of the plains of West Bengal can pose serious crop production and food safety risks, as rice plants irrigated with groundwater are known to absorb arsenic from soils, get into plant tissues, and also affect yields (Heikens, 2006).

## 9.0 Conclusions and Policy Inferences

Evidence available from both Indo-Gangetic plains and in peninsular India suggests that there is a strong nexus between surface irrigation development and sustainability of well irrigation. It is not prudent to invest in well irrigation without investment in large surface reservoirs and conveyance systems in semi arid and arid areas. Risks associated with such irrigation development policies are more in the hard rock areas. The spatial imbalance in water resource availability and water demand in India, which creates water-surplus regions and water-scarce regions, can be addressed only through surface water transfer projects.

Application of outdated irrigation management concepts lead to under-valuation of the benefits from surface irrigation. The positive externalities (social benefits) generated by surface irrigation, such as enhanced recharge of aquifers resulting from excessive return flows that sustain well irrigation; saving in cost of energy used for pumping groundwater; and improved food security resulting from lowering of cereal prices are missed out in the conventional benefit-cost calculations.

It is high time for the “die-hard” proponents of well irrigation to understand that water, whether well water or canal water, has to come from the same hydrological system. Promoting aquifer recharge using surface runoff from the same area, to sustain well irrigation is hydrological and economically absurd. The areas facing groundwater over-draft are having extremely limited surface water resources, and artificial recharge schemes are economically unviable. A better appreciation of this fact would help save public funds to the tune of thousands of crore, being spent for groundwater recharge schemes.

Using aggregate time series data on irrigated area to evaluate the returns on investments in surface irrigation systems will be highly misleading. They often cater to large urban water demands, which generate great social values, but reduce their irrigation potential; farmers irrigate their land through canal lifting, which get recorded as lift irrigation; and capacity of reservoirs decline over the years due to the natural process of siltation. Also, increase in groundwater draft in upper catchments and intensive water harvesting reduce stream flows in rivers, affecting the reservoir storage and irrigation potential. It is beyond the institutional capacity of state irrigation agencies to control such phenomena. It is obvious that for evaluating the performance of surface schemes vis-à-vis return on investment, it is important to look at the performance of individual schemes considering these factors. That said, the area under surface irrigation has steadily increased during the past five decades.

The groundwater abundant-eastern India will not be capable of driving growth in well irrigation in future. A greater recognition of the fact that availability of arable land, rather than the availability of groundwater, is a major determinant of regional growth in irrigation demand would change the paradigm of water resource development for irrigation. The challenge is to build large water resource systems that are capable of transferring water from abundant basins to water-scarce basins having plenty of arable land, with minimum negative consequences for environment and ecology in both donor and receiving basins.

Groundwater in many semi arid and arid areas suffers from poor quality owing to high mineral content and toxicity. They can pose new risks of crop production and food safety by affecting soils and plant tissues. To conclude, while problems facing canal irrigation are mostly of management, problems are of much higher order in the case of well irrigation, as both the physical and social science of managing groundwater is much less advanced.

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