Groundwater Irrigation in India: Gains, Costs and Risks

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Abstract

Groundwater has rapidly emerged to occupy a dominant place in India's agriculture and food security in the recent years. It has become the main source of growth in irrigated area over the past 3 decades, and it now accounts for over 60 percent of the irrigated area in the country. It is estimated that now over 70 percent of India's food grain production comes from irrigated agriculture, in which groundwater plays a major role. Since the development of groundwater irrigation has not largely been government or policy driven - has happened gradually through highly decentralized private activity, this revolution has gone largely unnoticed.

However, despite this huge significance, groundwater irrigation is heading for a crisis in India and needs urgent understanding and attention. The number of irrigation blocks considered overexploited is increasing at an alarming rate of 5.5 percent per year. The number of blocks in which, officially, the creation of wells must completely stop is scaling new heights every year. Yet, the sinking of wells continues rapidly at enormous private, public and environmental cost. The way India will manage its groundwater resource in the future will clearly have very serious implications for the future growth and development of the agriculture sector in India, as well as the alleviation of poverty in India.

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1. INTRODUCTION

Groundwater has rapidly emerged to occupy a dominant place in India's agriculture and food security in the recent years. It has become the main source of growth in irrigated area over the past 3 decades, and it now accounts for over 60 percent of the irrigated area in the country. It is estimated that now over 70 percent of India's food grain production comes from irrigated agriculture, in which groundwater plays a major role. Since the development of groundwater irrigation has not largely been government or policy driven - has happened gradually through highly decentralized private activity, this revolution has gone largely unnoticed.

However, despite this huge significance, groundwater irrigation is heading for a crisis in India and needs urgent understanding and attention. The number of irrigation blocks considered overexploited is increasing at an alarming rate of 5.5 percent per year. The number of blocks in which, officially, the creation of wells must completely stop is scaling new heights every year. Yet, the sinking of wells continues rapidly at enormous private, public and environmental cost. The way India will manage its groundwater resource in the future will clearly have very serious implications for the future growth and development of the agriculture sector in India, as well as the alleviation of poverty in India.

2. SIZE AND PROFILE OF INDIA'S GROUNDWATER RESOURCE AND DEVELOPMENT

The estimated total replenishable groundwater resource in India is 43.57 million hectare-meters per year, as shown in Table 2.1 below. The groundwater available for irrigation is estimated to be about 86 percent of this or 36.42 million hectare-meters (after allowing 14 percent for domestic, industrial and other uses). Out of this the utilizable groundwater resources for irrigation is 32.77 million hectare-meters, or 90 percent. The net draft so far is about 13.5 million hectare-meters, therefore, the ground water development is only about 37 percent of the potential in the aggregate. However, this does not reveal the geographic variation in this development which is rather extreme.

Table 2.1: Ground Water Resources of India, 1998 (in Million Hectare-Meters per Year)	
1. Total Replenishable Ground Water Resources	43.57
2. Provision for Domestic, Industrial and Other Uses	7.15
3. Available Ground Water Resources for Irrigation in Net Terms	36.42
4. (3) as percent of (1)	83.56
5. Utilizable Ground Water Resources for Irrigation in Net Terms	32.77
6. Gross Draft Estimated on prorate basis	19.29
7. Net Draft	13.50
8. Balance Ground Water Resources for future use in net terms	22.89
9. Level of Ground Water Development	37.08
Source: India, Central Ground Water Board 2003.	

What is the distribution by river basin in India? Table 2.2 which gives the river basin wise groundwater potential in the country shows that out of the total replenishable groundwater resources of 431.42 billion cubic meters, the Ganga basin alone accounts for nearly 40 percent. None of the other basins even cross 10 percent. The basins with more than 5 percent of the total replenishable potential are Godavari (9.42 percent), Brahmaputra (6.15 percent), Indus (6.14 percent) and Krishna (6.12 percent). This shows that the distribution of groundwater availability in India is very skewed.

What is the state-wise profile of irrigation potential and groundwater potential? The ultimate irrigation potential of the country is estimated to be about 140 million hectare. Of this the potential of groundwater is estimated to be 64 million hectare or 45.8 percent. Table 2.3 shows that the share of groundwater in the irrigation potential varies substantially from state to state. It is over 50 percent in states such as Uttar Pradesh, Madhya Pradesh, Jammu and Kashmir, and Manipur, to less than 33 percent in the case of Kerala, Haryana, and Assam.

Table 2.2: River Basin wise Ground Water Potential of the Country			
S. No.	Name of Basin	Total Replenishable Ground Water Resources (Billion Cubic Meters)	Percent-age
1	Ganga	170.99	39.63
2	Godavari	40.65	9.42
3	Brahmaputra	26.55	6.15
4	Indus	26.49	6.14
5	Krishna	26.41	6.12
6	Northeast Composite	18.84	4.37
7	Madras and South Tamil Nadu	18.22	4.22
8	Western Ghat	17.69	4.10
9	Mahanadi	16.46	3.82
10	Cauvery	12.3	2.85
11	Kutch & Saurashtra Composite	11.23	2.60
12	Narmada	10.83	2.51
13	Meghna	8.52	1.97
14	Tapi	8.27	1.92
15	Cambay Composite	7.19	1.67
16	Pennar	4.93	1.14
17	Brahmai with Baitarni	4.05	0.94
18	Subarnrekha	1.82	0.42
	Total Resources in BCM	431.42	100
	Source: India, Ministry of Water Resources 2007.		

Table 2.3: State-wise Ultimate Groundwater Irrigation Potential: 2001-02			
	Total Irrigation Potential (000 Ha.)	Ground Water Potential (000 Ha.)	Share of Ground Water in Total Ultimate Irrigation Potential
Manipur	604	369	61.1
Uttar Pradesh*	30499	16799	55.1
Madhya Pradesh*	17932	9732	54.3
Jammu & Kashmir	1358	708	52.1
Tamil Nadu	5532	2832	51.2
Punjab	5967	2917	48.9
West Bengal	6918	3318	48.0
Orissa	8803	4203	47.7
India	**139893**	**64050**	**45.8**
Gujarat	6103	2756	45.2
Karnataka	5974	2574	43.1
Maharashtra	8952	3652	40.8
Meghalaya	168	63	37.5
Bihar*	13347	4947	37.1
Andhra Pradesh	11260	3960	35.2
Rajasthan	5128	1778	34.7
Kerala	2679	879	32.8
Haryana	4512	1462	32.4
Assam	2870	900	31.4
Tripura	281	81	28.8
Goa	116	29	25.0
Himachal Pradesh	353	68	19.3
Arunachal Pradesh	168	18	10.7
UTs	144	5	3.5
Mizoram	70	0	0.0
Nagaland	85	0	0.0
Sikkim	70	0	0.0

Note : * : Figures include the Ultimate Irrigation Potential (UIP) for Jharkhand, Chhatisgarh, Uttaranchal in the UIP of Bihar, Madhya Pradesh and Uttar Pradesh respectively.

Source : India, Ministry of Water Resources 2007.

What is the level of development of the groundwater resource? Table 2.4 gives the state-wise profile of the groundwater resource, its availability for irrigation, net draft, and the percentage level of groundwater development. The states are arranged in descending order of the percent of groundwater

Table 2.4: State-wise groundwater resource and its development in India (as on Mar 31, 2003)

Sl. No.	States	Total Replenishable Groundwater Resource BCM/yr	Available Ground water Resources for Irrigation BCM/yr	Net Draft BCM/yr	Level of Ground water Development [%]
1	Haryana	8.53	7.25	8.13	112.18
2	Punjab	18.66	16.79	16.40	97.66
3	Rajasthan	12.71	10.71	9.26	86.42
4	Tamil Nadu	26.39	22.43	14.45	64.43
5	Gujarat	20.38	17.32	9.55	55.16
7	Uttar Pradesh	81.12	68.95	32.33	46.89
8	Bihar	26.99	22.94	10.63	46.33
9	**All India**	**431.88**	**360.80**	**149.97**	**41.57**
10	West Bengal	23.09	19.63	7.50	38.19
11	Maharashtra	37.87	25.47	9.44	37.04
12	Uttaranchal	2.70	2.29	0.82	35.78
13	Karnataka	16.19	13.76	4.76	34.60
14	Tripura	0.66	0.56	0.19	33.43
15	Jharkhand	6.53	5.55	1.84	33.13
16	Andhra Pradesh	35.29	30.00	8.57	28.56
17	Madhya Pradesh	34.82	29.60	8.02	27.09
18	Kerala	7.90	6.59	1.46	22.17
20	Orissa	20.00	17.00	3.61	21.23
21	Himachal Pradesh	0.37	0.29	0.03	10.72
22	Assam	24.72	21.01	1.84	8.75
23	Goa	0.22	0.19	0.02	8.30
25	Chhatisgarh	16.07	13.66	0.81	5.93
26	Meghalaya	0.54	0.46	0.02	3.97
27	Jammu & Kashmir	4.43	3.76	0.03	0.81
28	Arunachal Pradesh	1.44	1.22	Neg.	Neg.
29	Manipur	3.15	2.68	Neg.	Neg.
30	Nagaland	0.72	0.62	Neg.	Neg.

Note: 1995 estimates are projected to 2003. BCM – Billion Cubic Meter

Source: India, Ministry of Water Resources 2007.

development. The table shows that the distribution is extremely skewed ranging from 112 percent to negligible. The level of groundwater development is 112 percent in Haryana, 98 percent in Punjab and 86 percent in Rajasthan. This is followed by

Tamil Nadu at 64 percent and Gujarat at 55 percent, indicating huge differences across states. Further, these figures do not show the intra-state distribution, which is also very skewed.

What is the distribution of wells across India? The distribution of irrigation and wells in the states and villages can be seen through the statistics given in Table 2.5. Over 60 percent of the villages in India have tubewells. The states where percent of villages having tubewell irrigation is above national average are

Sr. No	Table 2.5: State-wise Number of Villages Having Irrigation Facility per 1000 Villages, and Their Distribution by Type of Such Facility in India : (July-December 2002)			
	States/UTs	Number of Villages Having Irrigation Facility per 1000 Villages	Percent of Villages having Tube-well Irrigation	Percent of Villages having Other well Irrigation
1	Punjab	976	92.2	2.4
2	Himachal Pradesh	382	83.5	0.0
3	Uttar Pradesh	987	82.1	2.2
4	Haryana	979	81.4	1.3
5	Bihar	895	68.6	0.4
6	**India**	**762**	**63.1**	**21.3**
7	Karnataka	829	59.3	11.7
8	Rajasthan	893	54.3	34.6
9	Gujarat	891	50.6	47.3
10	Chhatisgarh	652	44.6	11.3
11	West Bengal	845	43.9	7.3
12	Andhra Pradesh	796	43.8	7.8
13	Madhya Pradesh	925	40.6	39.6
14	Tripura	685	38.5	2.2
15	Uttaranchal	391	36.8	0.0
16	Orissa	281	31.3	0.0
17	Pondicherry	1000	24.4	0.0
18	Mizoram	188	22.3	68.1
19	Dadra & Nagar Haveli	573	22.3	22.3
20	Daman & Diu	749	19.2	36.0
21	Tamil Nadu	879	13.9	39.6
22	Maharashtra	804	9.5	72.1
23	Kerala	840	7.0	28.8
24	Arunachal Pradesh	355	6.2	0.0
25	Jammu & Kashmir	708	4.4	0.0
26	Sikkim	618	0.2	8.4
Source: India, Ministry of Water Resources 2007.				

Punjab, Himachal Pradesh, Uttar Pradesh, Haryana and Bihar. In states such as Maharashtra, Gujarat, Rajasthan and Madhya Pradesh, a large percentage of villages show the presence of other wells. However, in Gujarat, Rajasthan and Madhya Pradesh the frequency of tube-wells is also very high.

3. GROWTH OF GROUNDWATER IRRIGATION IN INDIA

The growth in irrigated area and the rising contribution of groundwater can be seen from the statistics given in Table 3.1 below. The net irrigated area has increased from 21 million hectares in 1950-51 to 56 million hectares in 2001-02. The share of groundwater irrigation through wells has risen from 28 percent to 62 percent. The main contribution has come from rapid growth in tubewell irrigation. The share of this has risen from zero in 1950-51 to over 40 percent by 2001-02.

Table 3.1: Sources of Irrigation in India: 1950-51 to 2001-02 (‘000 Hectares)

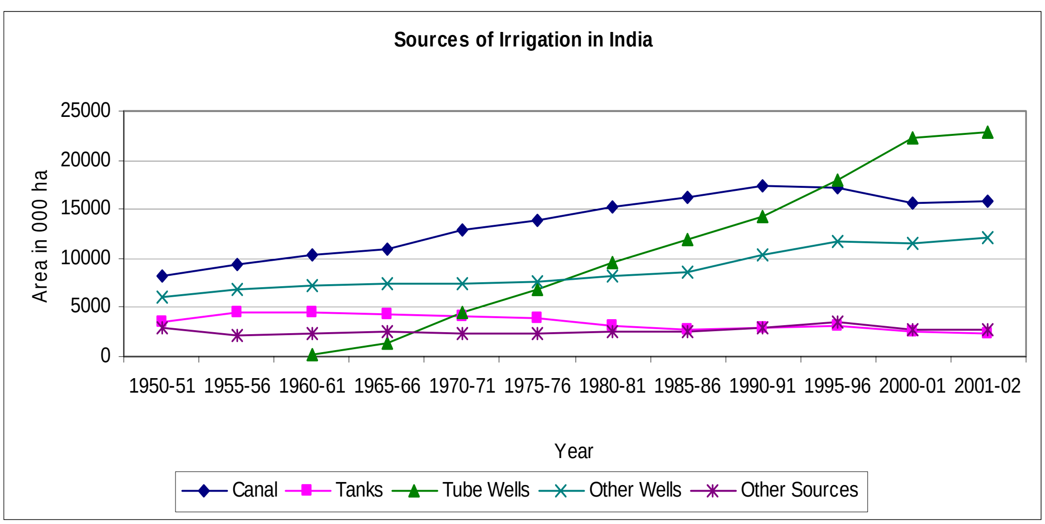
Year	Canal	Tanks	Tube Wells	Other Wells	Total Wells	Other Sources	Total Net Irrigated Area
1950-51	8295	3613	0	5978	5978	2967	20853
1960-61	10370	4561	135	7155	7290	2440	24661
1970-71	12838	4112	4461	7426	11887	2266	31103
1980-81	15292	3182	9531	8164	17695	2551	38720
1990-91	17453	2944	14257	10437	24694	2932	48023
1995-96	17120	3118	17894	11803	29697	3467	53402
2000-01	15710	2518	22324	11451	33775	2831	54833
2001-02	15877	2336	22816	12020	34836	2827	55876
Percentage Share of Various Sources							
1950-51	39.78	17.33	0.00	28.67	28.67	14.23	100
1960-61	42.05	18.49	0.55	29.01	29.56	9.89	100
1970-71	41.28	13.22	14.34	23.88	38.22	7.29	100
1980-81	39.49	8.22	24.62	21.08	45.70	6.59	100
1990-91	36.34	6.13	29.69	21.73	51.42	6.11	100
1995-96	32.06	5.84	33.51	22.10	55.61	6.49	100
2000-01	28.65	4.59	40.71	20.88	61.60	5.16	100
2001-02	28.41	4.18	40.83	21.51	62.35	5.06	100

Source: Gandhi and Namboodiri 2002.

The green revolution was a major force in this growth. Beginning in the mid-1960s, the green revolution was a major turning point in India's agriculture. The adoption of new seeds and fertilizers provided great benefits and the benefits were the best under irrigation. Large investments had been undertaken in surface water projects to provide irrigation water to larger numbers of farmers. A number of other significant changes also took place in the late 60's and 70's (Brisco and Malik 2006). Electricity supply expanded in rural areas making pumping of groundwater easy and economical. New modular well and pumping technologies became widely available. In the surface irrigated and flood-prone areas, water-logging and/or salinity were problems, and it was realized that encouragement of groundwater pumping provided an effective mechanism for lowering the groundwater table and reducing the severity of the problems. Farmers realized that groundwater was abundant in many areas, especially in the large alluvial basins. The reach of institutional credit expanded making credit more widely available. Farmers realized they could develop and apply water 'just in time' from groundwater sources, something which was not possible in the institutionally-complex and poorly managed canal systems.

The result was a quite revolution, in which groundwater irrigation developed at a very rapid rate, Brisco and Malik 2006, while tank irrigation declined and surface water irrigation grew much more slowly (see Figure 1).

Figure 1



Cheap and un-metered electricity, slow development of surface irrigation, and poor management of canal systems further encouraged groundwater development. Over the last two decades, 84 percent of the total addition to net irrigated area came from groundwater, and only 16 percent from canals (Brisco and Malik 2006). Thus, at present the net area irrigated by private tubewells is about double the area irrigated by canals.

In the early phase of groundwater development in the 1950s, after independence, the groundwater extraction was dominated by traditional dug wells with depths generally not exceeding 30 feet. Labour or animal devices such as Persian wheels were often used to lift the water, constituting over 60 percent of the irrigation devises. Frequently, there was conjunctive use and hydrological nexus between well irrigation and tank irrigation (Jeet 2005). With this and the crop choice, the balance between demand and supply of water could be maintained except during years of very low rainfall, and therefore, water use was generally sustainable.

The second phase starting in the 70s saw considerable growth of dug-cum-bore wells. The depth of the wells increased to about 50 to 100 feet and the use of centrifugal pumps became common. More water could be lifted leading to increase in irrigated area and growing of crops with greater water requirement. With the easy availability of institutional credit for the construction of wells in the mid 1970s , the number of wells increased substantially by late 1970. On the other hand, most of the tanks became unusable for irrigation due to poor maintenance and this resulted in even greater dependence on groundwater.

During the third phase beginning from mid-1980s, the extraction technology started changing towards submersible pumps and the depth of wells increased to beyond 400 feet in many areas. Water extraction increased rapidly, under the influence of subsidies on electricity, lack of metering, credit availability, and the commercialization of agriculture (Singh 2003). This led to rapid declines in the water table, decline in the quality of water, increased frequency of well failure and rapidly rising costs of well investment and operation. This expansion of groundwater use has resulted in a speedy decline in the groundwater table in several parts of the country (Dhawan, 1995; Moench 1992; Bhatia, 1992).

The number of shallow wells doubled roughly every 3.7 years between 1951 and 1991 (Moench, 2003), the total crossing 18.5 million wells nationwide and accounting for over 50 percent of the irrigated area. Groundwater now provides for about 60-70 percent of the irrigated area, and about 80 percent of the domestic water supply. The rapid expansion has resulted in steep declines in the groundwater table, low productivity of wells, intrusion of sea water in many areas and the deteriorating the groundwater quality. In arid regions such as Rajasthan and Gujarat, ingress of naturally occurring brackish groundwater has become a matter of great concern. According to IWMI, the withdrawal rate in India is twice the recharge rate. Thus, even though groundwater is a powerful tool for poverty reduction, developing and managing this resource in a sustainable way is tremendous challenge. Attempts to regulate groundwater through restrictions on credit and electric connections has had very little effect.

4. THE RELATIVE EFFICACY, EFFICIENCY AND EQUITY OF GROUNDWATER V/S. SURFACE WATER

How does groundwater compare with surface water? Important work on this has been done by Moench 2003, and this section draws substantially on this research. Irrigation plays a major role in green revolution technologies and within this, groundwater irrigation is best (Moench, 2003). This is documented in a number of studies (see Meinzen-Dick 1996, Shah 1993). Farmers owning wells generally achieve the highest yields while those purchasing water from well owners achieve yields higher than those dependent on canal irrigation alone but not as high as the yields achieved by well owners, see Table 4.1 and 4.2 based on these studies. Well irrigation is also associated with higher cropping intensity, higher cash input expenditure and higher gross income per acre.

Table 4.1: Average Yields of Major Crops by Water Source				
Crop	Canal Only	Public Tubewell	Purchased from Tubewell	Own Tubewell
Yield (Kg/acre)				
Wheat	672	747	784	896
Rice	522	709	784	859
Cotton	261	299	373	485
Source: Moench 2003, Meinzen-Dick 1996, and Freeman and Lowdermilk 1978.				

Table 4.2: Input Use and Agriculture Productivity by Water Source			
	Canal Water Only	Tubewell Water Buyers	Tubewell Owners
Gross crop income (Rs/acre)	3,018	3,475	4,659
Canal Water use/acre (acre minutes)	26.3	26.2	25.2
Tubewell water use (acre minutes)	0.0	14.2	31.4
Cash input expenditure (Rs/acre)	309	385	388
Labour use (man-days/acre)	73.8	76.2	75.5
Cropping intensity (percent)	160	168	184
Percent water consumptive crops	35	36	45
Source: Moench 2003, Meinzen-Dick 1996, and Renfro 1982			

Other research indicates that yields in groundwater irrigated areas are higher by one-third to one-half as compared to those from areas irrigated by surface sources (Dhawan 1995). A wholly irrigated acre of land may become equivalent to 8 to 10 acres of dry land in production and income terms (Dhawan 1993). Some estimates suggest that as much as 70-80 per cent of India's agricultural output may be groundwater based (Dains and Pawar 1987). It is also found that well owners and those purchasing water tend to make more complementary investments in fertilizer, labour and other inputs (Kahnert and Levine 1989). This increases the demand for these inputs and help rural development (Moench, 2003).

Shah 2003 indicates that numerous micro-level studies based on sample surveys show that pump-irrigated farms perform much better compared to those irrigated by any other source in terms of cropping intensity, input use and yields; (see, e.g., Dhawan 1985). By common observation, this difference between areas irrigated by private tube wells and those irrigated by gravity flow canals is obviously explained by superior quality in terms of reliability, timeliness, adequacy of irrigation that tube wells offer compared to other sources (Chambers et al. 1987, Shah 1993).

Groundwater offers reliability and control of water in irrigation which is very important. Experiments elsewhere indicate that water control alone can bridge the gap between potential and actual yields by about 20 per cent (Herdt and Wickham 1978). In Spain, irrigation uses 80 per cent of all water and 20 per cent of that water comes from underground. But the 20 per cent produces more than 40 per cent of the cumulative economic value of Spanish crops (Barraque, 1997). The role of groundwater is not just through higher yields. In arid regions, the stabilization effect of groundwater development may be substantial and have more than twice the benefit value of increase in water supply (Tsur 1990). In southern California, the stabilization value in agriculture is, in some cases, as much as 50 per cent of the total value of groundwater (Tsur 1993). The economic impact of droughts in California in the early 90's was minimal largely because farmers were able to shift from unreliable surface supplies to groundwater (Gleick and Nash 1991).

In the Indian context, some insight on this can be gained through examining the impact of different droughts (Moench 2003). In the 1960s groundwater irrigation was a relatively insignificant, particularly in eastern India. In 1965-66, when the monsoon rainfall was 20 per cent below normal, the foodgrain production declined by 19 per cent at the all India level over the 1964-65 production level (Prasad and Sharma 1991). In 1987-88 when groundwater had been considerably developed, the rainfall dropped by 17.5 per cent below normal, and yet the foodgrain production declined by only 2.14 per cent from the previous year. (Note: the droughts are not strictly comparable.)

Another way is to compare the standard deviation in the growth rates of irrigated and unirrigated agriculture for the period after the advent of new technology in late 1960s. Analysis carried out for eleven major states, for the period 1971-84, reveals that the degree of instability in irrigated agriculture is less than half of that in unirrigated agriculture (Rao and Ray 1988) (see Table 4.3). The stability impact of irrigation is found to be much greater in low rainfall states, especially those served by assured sources of irrigation including tubewells (Haryana and Punjab), than that in high rainfall areas, indicating an impact of groundwater irrigation. Bihar and Madhya Pradesh are the only states that exhibit higher fluctuation in irrigated agriculture compared to that in unirrigated agriculture.

Table 4.3: The impact of irrigation on variability in agricultural output

State	Irrigated Agricultural Output (1)	Unirrigated Agricultural Output (2)	Unirrigated to Irrigated Ratio (3=2/1)
Standard Deviation in Annual Growth Rates, 1971-84			
Andhra Pradesh	13.6	18.8	1.38
Bihar	22.0	17.9	0.81
Gujarat	23.8	86.3	3.63
Haryana	9.3	54.8	5.89
Karnataka	16.7	31.4	1.88
Madhya Pradesh	24.5	23.0	0.94
Maharashtra	17.9	43.8	2.45
Punjab	4.9	19.3	3.94
Rajasthan	11.3	46.9	4.15
Tamil Nadu	19.2	41.6	2.17
Uttar Pradesh	12.0	40.0	3.33
Average	7.3	19.0	2.60

Source: Moench 2003, adapted from Rao and Ray 1988

What is the nature of ownership and equity in groundwater irrigation? The Third Minor Irrigation Census conducted in 33 states and Union Territories during the year 2000-01 enumerates 18.5 million groundwater units. These comprise of 9.62 million dug wells, 8.35 million shallow tubewells, and 5.30 million deep tubewells. The distribution of well irrigation units by their ownership (Table 4.4) shows that 81 percent of dugwells are owned by individual farmers, 16.8 percent by groups of farmers, and very few by others. In shallow tubewells, 94.6 percent are owned by individuals, 4 percent by groups of farmers, and very few by others. In deep tubewells too, 61.8 percent are owned by individuals, 27.6 percent by group of farmers, and about 10 percent by the government/co-ops./panchayat. On the other hand, the ownership of the surface flow schemes is dominated by the government. Thus, the ownership of tubewells and dug wells is largely with private individual farmers. Only in the case of deep tubewells, groups of farmers and government show some ownership, but individual farmers still dominate.

Table 4.4: Distribution of Wells according to their Ownership: 2000-01					
	Dugwells	Shalllow Tubewell	Deep Tubewell	Total	Surface Flow
Distribution According to Ownership(Number: 1000)					
Government	172.0	47.8	50.3	270.2	264.8
Coop. Societies	9.7	7.2	1.9	18.8	2.5
Panchayat	14.4	18.9	3.5	36.8	45.7
Group of Farmers	1611.4	334.8	146.5	2092.8	98.2
Individual Farmers	7784.5	7901.7	0.0	15686.2	217.0
Others	25.2	45.4	328.0	398.5	13.9
Total	9617.4	8355.7	530.2	18503.2	642.0
Distribution According to Ownership(Percentage)					
Government	1.79	0.57	9.49	1.46	41.24
Coop. Societies	0.10	0.09	0.36	0.10	0.38
Panchayat	0.15	0.23	0.66	0.20	7.11
Group of Farmers	16.76	4.01	27.64	11.31	15.29
Individual Farmers	80.94	94.57	0.00	84.78	33.80
Others	0.26	0.54	61.86	2.15	2.17
Total	100.00	100.00	100.00	100.00	100.00
Source: India, Ministry of Water Resources 2002.					

What is the ownership pattern by land holding size? Results from the same survey given in Table 4.5 indicate that over 67 percent of the dugwells and shallow tubewells are owned by small and marginal farmers – those having operational holdings below 2 hectare. In the case of deep tubewells, about 60 percent are owned by medium and large farmers. In the case of surface water, small and marginal farmers have a 72 percent share. Thus, groundwater irrigation is less equitable than surface irrigation by landholding size, and deep tubewells are even less equitable. However, over two-thirds of dugwells and shallow tubewells are owned by small and marginal farmers.

Small and marginal farmers operate 36 percent of the land whereas medium and large farmers operate 64 percent of the land. Of all the wells, 66 percent are owned by small and marginal farmers, and 34 percent are owned by medium and large farmers. This indicates that compared to land ownership, the distribution of wells is equitably and is skewed in favour of small and marginal farmers. However, surface irrigation is more favourably distributed, with 72 percent access with small and marginal farmers.

Table 4.5: Distribution of Wells according to Farm Holding Size: 2000-01

Operational Holding Size	Dugwells	Shallow Tubewell	Deep Tubewell	Total	Surface Flow	Number of Operational Holdings (1995 in 000)	Area Operated (1995 in 1000)
Distribution According to Farm Holding Size (Number:1000)							
Marginal(0-1 ha)	3222.5	2731.5	24.7	5978.7	111.7	71179	28121
Small(1-2 ha)	2924.9	2890.5	35.7	5851.1	114.2	21643	30722
Medium(2-10 ha)	3007.9	2273.6	68.5	5350.0	65.5	21353	80351
Large (>10 ha)	240.7	340.9	17.6	599.2	23.8	1403	24163
Total	9396.0	8236.5	146.5	17779.0	315.2	115580	163357
Distribution According to Farm Holding Size (Percentage)							
Marginal(0-1 ha)	34.30	33.16	16.85	33.63	35.45	61.59	17.21
Small(1-2 ha)	31.13	35.09	24.38	32.91	36.22	18.73	18.81
Medium(2-10 ha)	32.01	27.60	46.75	30.09	20.77	18.47	49.19
Large (>10 ha)	2.56	4.14	12.02	3.37	7.56	1.21	14.79
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Source: India, Ministry of Water Resources 2002, India, Department of Agriculture & Cooperation 1997.

Table 4.6: Crop Season Wise Area Irrigated by Groundwater: 2000-01

	Dugwells	Shallow Tubewell	Deep Tubewell	Total
Crop Season Wise Area Irrigated by Groundwater (1000 Ha.)				
Kharif	4745.0	10676.6	1415.2	16836.7
Rabi	6988.1	13284.7	2000.0	22272.7
Perennial	1098.3	2259.0	408.5	3765.7
Others	391.9	1452.7	262.4	2107.0
Total	13223.2	27673.0	4086.0	44982.2
(Percentage)				
Kharif	35.88	38.58	34.63	37.43
Rabi	52.85	48.01	48.95	49.51
Perennial	8.31	8.16	10.00	8.37
Others	2.96	5.25	6.42	4.68
Total	100.00	100.00	100.00	100.00

Source: India, Ministry of Water Resources 2002.

The distribution of crop season wise irrigation by groundwater indicates that more area is irrigated by groundwater in the rabi season – about 50 percent, about 35-38 percent in the kharif season, and about 8-10 percent in perennial crops, Table 4.6. Thus, rabi season, when rainfall is low, takes the major share of groundwater.

Moench, 2003 writes that the equity impacts of groundwater development for irrigation are not all positive. The modern tubewell drilling and technology tends to be capital intensive. As a result, large farmers have an advantage. Early exploiters of groundwater have typically been large farmers who produce surpluses for the market. World Bank 1999 indicates that tying water rights to land rights has implications for access to groundwater and has led to *de facto* rights at the field level where, due to the characteristics of groundwater as a common property resource, larger farmers with higher pumping capacity and deeper tubewells have a disproportionate claim over the resource than others. Singh, 2003 indicates that this can be partly solved by water markets, which can mitigate the inequalities in the access to groundwater. Farmers who do not have their own well can have access to groundwater irrigation through water markets.

In this context of inequality, Shah 2003 indicates that are compelling reasons for stimulating rapid development of groundwater resources in eastern India. Eastern India has the bulk of India's poverty. It is largely rural, predominantly agricultural, and has a high population density. It has been argued that the green revolution in Punjab, Haryana and Western UP was fueled more by the private tube-well revolution, and that its has not progressed eastward to eastern India is explained by the slow pace of groundwater development in the east (Dhawan 1982). Besides, increased density of wells can increase the welfare of the people in the eastern region through the powerful positive externality they produce by working against waterlogging and flood-proneness. Centre for Science and Environment (CSE 1991, Shah 2003) states that: "…that active development of groundwater reservoirs by extensive irrigation pumping during dry season can provide substantial capacity to store flood and drainage waters during the wet season. Preliminary calculations made in USA indicate that full development of conjunctive use in the Ganga basin can lead to as much as 50 per cent reduction in the monsoon flow of the river. Thus, groundwater utilization can not only contribute to full realization of the agricultural potential of the region but would also be effective in reducing and preventing waterlogging conditions which have come to be an imminent threat in considerable tracts of North Bihar [as indeed much of Eastern India]. The measure could considerably alleviate the flood problem of the region through provision of underground storage of monsoon flows. However, the desired development of groundwater in this area has been inhibited by the preponderance of marginal farmers who cannot afford the investment required in installation of tube wells….”

5. THE ROLE OF LAND TENURE, WATER RIGHTS AND GROUNDWATER MARKETS IN INFLUENCING EQUITY AND EFFICIENCY

As per the laws, groundwater is under private regime in India and the rights to groundwater belong to the land owner (Jeet, 2005). The right to groundwater would be transferred to anyone to whom the land is transferred. There is no limitation on how much groundwater a particular land owner can draw. Therefore a land owner can legally abstract any amount of water unless the geo-hydrology or technology limits it. The consequence of such a legal framework is that only the landowners can own groundwater in India. The landless households or tribes who have community rights over land have no private rights. The legal framework also implies that rich landlords can be water lords and indulge in open extraction and selling as much as they wish (Singh 1991). The lack of well-defined property rights, the invisibility, and the complex flow characteristics of ground water makes it very difficult to monitor the use of groundwater (Singh 1995).

For wider access and control, it is necessary to separate water rights from land rights, but no such provisions have been made so far in the national groundwater law (Jeet, 2005). In Gujarat the government has tried to regulate water extraction and marketing by restricting the depth of tubewells and by introducing licensing procedures, but there is little success. Since the groundwater situation in different parts of the country vary with factors such as geology, hydrology, ecology, soil, climate, pattern of usage, and water quality, the nature of regulations for groundwater utilization may need to vary from area to area.

Water markets and trading can partly mitigate the inequalities in the access to groundwater resources due to lack of ownership of land, Jeet 2005. They could work on the principle of profitability and through this over exploitation could be checked. Though water markets exist, by and large, they are limited to localized water trading between adjacent farmers. Water trading remains informal in the sense that there are often no formal methods or agreements. This hinders the reallocation of water for more productive use. In recent years it has become apparent that informal water markets have become widespread. One of the more complex and better operated of these informal markets is in Gujarat (World Bank 1999). Expanding the role of markets into a formal mechanism for water allocation necessitates a reform of the water rights framework, and the development of effective management institutions (World Bank 1999). The introduction of more formal water markets, where feasible, could further provide opportunity for efficient reallocation using market mechanisms (World Bank, 1999).

Who participate in the water market is an important indicator of the nature of water markets. Past studies show that the well owners with less holding have a higher extent of participation than those who owned larger holdings (Shah and Raju 1988). But a Study done in Rajasthan (Singh 2003) does not support this hypothesis, see Table 5.1 below. The study shows that among the sellers only one-third belong to the small and semi-medium size categories - two-thirds belonged to the medium and large farm size categories. On the other hand the majority of the buyers belonged to the small and semi-medium size groups.

Table 5.1: Farm size-wise distribution of households participating in water markets (percent)						
Category	Size of Farms					Sample Size (No.)
	Marginal	Small	Semi-Medium	Medium	Large	
Kukanwali						
Self-users	0	0	15	77	8	13
Seller	0	11	21	42	26	19
Buyers	25	13	50	12	0	8
Overall	5	8	25	42	15	40
Srichandpura						
Self-users	17	50	33	0	0	6
Seller	33	33	34	0	0	6
Buyers	70	15	15	0	0	13
Overall	48	28	24	0	0	25
Overall						
Self-users	5	16	21	53	5	19
Seller	8	16	24	32	20	25
Buyers	52	14	29	5	0	21
Overall	22	15	25	29	9	65
Source: Singh 2003						

The same study finds that the major reasons behind the non-participation given by self-users are lack of surplus water on account of low discharge, followed by no buyers, and water quality, Table 5.2. On the other hand, the reasons for participation given by sellers were surplus water, profit earning and power policy. The major reasons given for participation by the buyers were no well though they own, and unreliable power supply.

Table 5.2: Reasons for participation or non-participation in water markets (percent)			
Particulars	Kukanwali	Srichandpura	All
Self-Users' Reasons for not participating			
• No Surplus Water	46	83	58
• No Buyers	38	17	32
• Water Quality	16	0	10
Sellers' Reasons for Participating			
• Surplus Water	74	83	76
• Profit Earning	26	50	32
• Power Policy	26	17	24
Buyer's Reasons for Participating			
• Owned Land but No Well	88	46	66
• Limited and Fluctuating Water Supply	12	54	34
Source: Singh 2003			

Apart from the water markets, an important grassroots initiative on improving the groundwater availability has been the checkdam movement in the Saurashtra region of Gujarat. This involved the formation of village level local institutions in hundreds of villages to undertake the planning, finance and construction of a system of checkdams in an around the village to collect and hold rainwater so as to recharge the underground aquifers and thereby recharge the dug wells. The movement appears to have had a huge impact on water availability and agricultural incomes in the area. The results of a study of these institutions, Gandhi and Sharma 2009, Table 5.3, indicates a large positive impact on water availability, irrigated area, participation-empowerment, village development and the environment.

Table 5.3: Impact of rainwater harvesting and groundwater recharge by checkdam groups of Saurashtra region in Gujarat – response of members

	Percent				
Questions on the impact on: Scarcity and Efficiency Equity Empowerment Development and Environment	Highly Positive	Positive	No Impact	Negative	Highly negative
Timely water availability	44	56	0	0	0
Adequate water availability	56	44	0	0	0
Increase in Irrigated Area	45	55	0	0	0
Equitable distribution of water	0	0	100	0	0
Empowerment of farmers to manage irrigation systems	42	58	0	0	0
Beginning of a sense of ownership by farmers	61	39	0	0	0
Active involvement of all classes	30	70	0	0	0
Village as a whole	91	9	0	0	0
Environment and natural resources	83	17	0	0	0

Source: Gandhi and Sharma 2009.

6. OVEREXTRACTION, COSTS AND EXTERNALITY IMPLICATIONS

Table 6.1 below shows the distribution of different talukas/ blocks in India into overexploited/ dark/critical with respect to the status of groundwater. The situation may not look serious at the national level since the number of such blocks is below 15 percent overall, and low in most states. However, the situation seems to be very precarious in states such as Punjab, Haryana, Rajasthan, and Gujarat. In these locations the incidence is high and the situation is becoming critical.

Table 6.1: Categorization of block/talukas/watersheds as overexploited and dark/critical

		Number of Districts	Number of Block/ Taluka/ Watershed	Overexploited		Dark/Critical		Year
				Number	Per-cent	Number	Per-cent	
1	Andhra Pradesh	22	1157	118	10.2	79	6.8	2001
2	Arunachal Pradesh	3		0	0.0	0	0.0	1998
3	Assam	23	134	0	0.0	0	0.0	2001
4	Bihar	42	589	6	1.0	14	2.4	2002
5	Chhatisgarh	16	145	0	0.0	0	0.0	1998
6	Goa	3	12	0	0.0	0	0.0	1998
7	Gujarat	20	184	41	22.3	19	10.3	1997
8	Haryana	17	108	30	27.8	13	12.0	2002
9	Himachal Pradesh	12	69	0	0.0	0	0.0	1998
10	Jammu & Kashmir	14	123	0	0.0	0	0.0	2002
11	Jharkhand	13	193	0	0.0	0	0.0	2002
12	Karnataka	19	175	7	4.0	9	5.1	1998
13	Kerala	14	154	3	1.9	6	3.9	1999
14	Madhya Pradesh	45	459	2	0.4	1	0.2	1998
15	Maharashtra	29	231	0	0.0	34	14.7	1998
16	Manipur	6	26	0	0.0	0	0.0	1998
17	Meghalaya	5	29	0	0.0	0	0.0	1998
18	Mizoram	3	20	0	0.0	0	0.0	1998
19	Nagaland	7	21	0	0.0	0	0.0	1998
20	Orissa	30	314	0	0.0	0	0.0	1999
21	Punjab	17	138	81	58.7	12	8.7	2002
22	Rajasthan	32	236	86	36.4	80	33.9	2001
23	Sikkim	4	4	0	0.0	0	0.0	1998
24	Tamil Nadu	27	385	135	35.1	35	9.1	1998
25	Tripura	3	17	0	0.0	0	0.0	2001
26	Uttar Pradesh & Utranchal	74	822	2	0.2	20	2.4	2000
27	West Bengal	16	341	0	0.0	61	17.9	2002
28	UTs		20	5	25.0	2	10.0	1998
	All India	516	6106	516	8.5	385	6.3	

Unit of Assessment: Andhra Pradesh, Maharashtra: Watershed; Gujarat, Karnataka: Taluka; Rest of the states-Blocks

Over-exploited: >100%; Dark: >85% - <100%

Source: Central Ground Water Board 2003.

The government's supportive policies for agriculture have made subsidies and credit available to the farmers, Singh 2003. There are strong linkages between power pricing, technology use, equity and efficiency in groundwater development. These have fostered intensive groundwater utilization. A sharp increase in groundwater use has been recorded, leading to over-exploitation of groundwater. The expansion of groundwater use has resulted in a speedy decline in the groundwater table in several parts of the country (Dhawan, 1995; Moench 1992; Bhatia, 1992). The evidence indicates that the fall in the water table is quite rapid in water scarce regions. In Rajasthan this decline is recorded at the rate of one to five metres per year in varying conditions. If this trend continues then there will be irreparable loss and socio-economic and environmental challenges will emerge. Immediate attention needs to be given to this.

Much has been written on groundwater over-extraction and quality concerns in India but there real dimensions remain difficult to evaluate, Moench 2003. Perceptions of widespread over-extraction stem from two pieces of strongly suggestive data: (1) the rapid growth in pump numbers and power consumption related to agricultural irrigation; and (2) clear evidence of substantial water level declines in selected areas along with data suggesting that such areas are increasing rapidly. Groundwater extraction in India has increased dramatically over the five decades since Indian Independence. Official statistics and projections all indicate rapid growth in the area irrigated from groundwater, the number of wells and the number of energized pump sets (World Bank 1998). Data from the groundwater component of the World Bank-Government of India water sector strategy review (World Bank 1998) clearly show the rapid rates of growth.

Further, the situation on the ground indicates that official figures are underestimates, Moench 2000. The number of energized pumps, for example, is estimated based on loan and subsidy applications through NABARD. Loans and subsidies are not given in areas that have been declared as “dark” due to groundwater over-extraction. However, well drilling continues based on private sources of finance - such wells are not captured in official statistics and the numbers could be large. In Mehsana District of Gujarat, for example, estimates indicate that some 2000 wells may be drilled annually despite the region having been “dark” for more than a decade (Moench and Kumar 1995). Furthermore, until relatively recently there was substantial political pressure at the local level to ensure that regions were not declared "dark". Subsidies and votes tend to go together in all parts of the world and in India this appear to have had an impact on some groundwater extraction estimates (Moench 1994)

There is no charge on groundwater itself and the present groundwater pricing structure provides minimal incentives for efficient and sustainable groundwater utilization. For electric pump-sets, almost throughout India, charges are levied on a flat rate basis per in proportion to the size of the pump set. Such non-volumetric charging only very indirectly bears to actual water use (World Bank, 1999). Moreover in most areas power is supplied to the rural areas are with heavy subsidy element. Groundwater is a key resource for poverty alleviation and economic development. Evidence indicate that improved water source generate many positive externalities in the overall household micro-economy. In areas dependent on irrigation agriculture, the reliability of groundwater and the higher crop yield generally achieved as a result often enable farmers with small holdings to increase their income (Moench, 2003). Similarly the positive impact of well irrigation goes beyond the well owners as it stabilizes demand for associated inputs, demand for more labour. Therefore the expansion of well irrigation has ripple effect in creating rural employment.

Despite the apparent widespread nature of the groundwater mining and pollution problems, the real extent may not be recognized since the official statistics on the number of blocks where extraction is approaching or exceeding recharge may be misleading. There is great uncertainty over these estimates (Moench 2000). The average figure of water availability show that the annual replenishable groundwater resources of India amounts to about 430 billion cubic meters, and that the net withdrawal amounts to about 160 bcm per year. This does not seems to be as a grave problem based on these numbers and averages. But averages are deceptive and most water issues are largely local issues. At the local level a huge number of the productive localities are already under severe groundwater stress. For the country as a whole, about 14 percent of all blocks are either over exploited or critical, a number of which is expected to reach 60 percent in just 25 years time (Briscoe 1996). Groundwater is now being abstracted at unsustainable rates in many areas seriously depleting reserves. The rapid development in groundwater, without regulatory or replenishment measures, would pay a great price namely depletion of water table at an alarming rate, water quality deterioration, and high cost of water extraction etc. One of the major problems of water table depletion and quality deterioration is on the health of large sections of population who heavily depend on groundwater. In Gujarat, groundwater supplies most domestic and more than three quarters of irrigation water. Over-extraction has caused the water table to fall by as much as 40 to 60 meters in many places, the yield of wells has decreased, cost of water pumping increased, and in many cases wells are being abandoned. The groundwater mining in Gujarat and Rajasthan has resulted in fluoride contamination endangering particularly the poor in these areas.

Most discussions of groundwater overdraft emphasize the distinction between economic depletion (i.e., falling water levels make further extraction uneconomic) and the actual dewatering of an acquifer. Acquifers are depleted in an economic sense long before there is any real threat of being dewatered. The Gangetic basin may have 20,000 feet of saturated sediment but from an agricultural perspective only the top few hundred feet are economically accessible for irrigation. Furthermore, wells owned by small farmers are shallow, only a few tens of feet deep. Putting this back in the context of poverty and famine, falling water tables will tend to exclude the poor – those who can't afford the cost of deepening wells – long before they affect water availability for wealthy farmers and other affluent users (Moench 1992).

The impact of this would tend to be particularly pronounced during drought periods when large number of small farmers could simultaneously lose access to groundwater when their wells dry up, Moench 2003. An increasing problem would also occur during non-drought periods as water-level declines undermined the economic position of small marginal farmers forcing them onto already saturated unskilled agricultural and urban labour markets. The food security crisis in both these situations would be economic rather than related to food grain availability per se.

A region where one of the most extensive over-extraction of groundwater has taken place in the country is north Gujarat. Tubewell depths have crossed 1000 ft in this area. Results from a recent study, Gandhi and Roy 2009, Table 6.2, indicate that hardly any institutional change has taken place so far to deal with the situation. The institutions do make an assessment of the quantity of water available and do well in more equitably distributing the water among members. However, no attempt is made to price the water according to its scarcity value and use. The members are aware that the activity of the institution is depleting groundwater in the village, but no effort is made by the institution to monitor or control the depletion and environmental harm. Equity is addressed but scarcity and environmental harm/ depletion are not being addressed.

Table 6.2: Responses on institutional questions from members of groundwater partnerships and cooperative institutions in north Gujarat.

		Percent				
	Questions on: Scarcity Equity Environment Finance	Strongly Agree	Agree	Partially Agree / Disagree	Disagree	Strongly Disagree
1.	The institutions assesses the quantity of water available in a season/ year	69	31	0	0	0
2.	The institution has processes for determining the allocation of this water to the farmers	62	38	0	0	0
3.	The institution prices the water according to its scarcity value	4	0	0	65	31
4.	The institution prices the water according to the crop	12	1	0	24	63
5.	The institution has processes for equitable distribution of the water among the farmers	54	46	0	0	0
6.	There is proper distribution of water between small and large farmers	51	48	1	0	0
7.	There is proper distribution of water between head, middle, and tail end farmers	53	46	1	0	0
8.	Equitable allocation of water is monitored and enforced	7	34	45	13	1
9.	The activity of the institution is causing flooding/ water logging in some areas	0	0	0	23	77
10.	The activity of the institution is rapidly depleting ground water in the village	36	64	0	0	0
11.	The institution is aware of and monitors such environmental harm/ depletion	0	0	1	53	46
12.	The institution is financially viable	0	0	100	0	0
13.	The institution is able to raise recurring payments from the beneficiaries	14	86	0	0	0

Source: Gandhi and Roy 2009.

7. GROUNDWATER QUALITY PROBLEMS

Sharma and Kumar 2005, indicate that problems are emerging even in areas such as the Krishna delta in Andhra Pradesh which is an agriculturally productive area known for its high crop yields. Due to insufficient supply of canal water, the dependence of farmers on groundwater for irrigating the crops has increased many-fold during the last decade. The existing groundwater salinity problem has worsened as a result of unplanned groundwater development. An in-depth analysis of the hydrogeologic conditions was made. Development of a two-dimensional cross-sectional model and subsequent simulations showed that the increase in groundwater salinity in the region except close to coast, was not due to active saltwater intrusion from the sea but due to saline water intrusion from existing saline zones into freshwater zones because of groundwater extraction.

Babaria, Solanki, Ardeshana and Barad 2005, examine the quality of underground irrigation waters of water scarce Saurashtra region of Gujarat. A survey of irrigation water of seven districts of Saurashtra (Gujarat) was undertaken. A total of 169 underground well/tubewell water samples were collected from the cultivate fields. Survey data indicated a range of EC (0.5 dS m^{-1}) to EC (23.0 dS m^{-1}). The overall mean value (5.87 dS m^{-1}) was higher than the critical value, and this is indicative of potential development of saline soils in these districts. By district, the highest mean value of pH 9.8 was recorded in Amreli district and the lowest mean value of pH 6.7 was recorded in Junagadh district. The overall mean value of SAR was 10.13.

8. THE EFFICACY OF WATER INSTITUTIONS (LAWS AND POLICIES) IN MANAGING THE GROUNDWATER CHALLENGES

As has been indicated above, groundwater is under private regime in India and the rights to groundwater belong to the land owner. The rights to groundwater are transferred to anyone to whom the land is transferred. There is no limitation on how much groundwater a particular land owner can draw. Therefore a land owner can legally abstract any amount of water unless the geo-hydrology or technology limits it. The consequence of such a legal framework is that only the landowners can own groundwater in India. The landless households or tribes who have community rights over land have no private rights. The legal framework also implies that rich landlords can be water lords and indulge in open extraction and selling as much as they wish (Singh 1991). The lack of well-defined property rights, the invisibility, and the complex flow characteristics of ground water makes it very difficult to monitor the use of groundwater (Singh 1995). Besides this, water is a state subject in India under the constitution.

The Ministry of Water Resources proposed a Bill on Groundwater Control and Regulation in 1970 and revalidated in 1992 and circulated to all state governments. Some of the major elements of this included powers to notify areas for control and regulation of groundwater development, grant of permission to extract and use groundwater in the notified areas, registration of existing users in the notified areas, prohibition of carrying on sinking wells in the notified areas and so on. But it failed to take off. There was no clause to involve the users or user group in the management structure.

Given the above status of the groundwater in the country, the Government of India has recently brought out a National Water Policy 2002 (India, Ministry of Water Resources 2002a) and this also focuses on groundwater resources. The policy states that:

1 "There should be a periodical reassessment of the groundwater potential on a scientific basis, taking into consideration the quality of water available and economic viability of its extraction.
2 Exploitation of groundwater resources should be so regulated as not to exceed the recharging possibilities, as also to ensure social equity. The detrimental environmental consequences of overexploitation of groundwater needed to be effectively prevented by the Central and State Governments. Groundwater recharge projects should be developed and implemented for improving both the quality and availability of groundwater resources.

3 Integrated and coordinated development of surface water and groundwater resources and their conjunctive use should be envisaged right from the project planning stage and should form an integral part of the project implementation.

4 Overexploitation of groundwater should be avoided especially near the coast to prevent ingress of seawater into sweet water aquifers."

However, the National Water Policy as well as other policy statements have not been translated into action, Jeet 2005. This is primarily because they are not supported by institutional structures, laws and other mechanisms. The legal and absolute right to groundwater rests with the land owner. Transferability of ownership independent of land is not defined. Tying water rights to land rights has implications for access to groundwater and distribution of benefits from water use, and also constraints the potential for inter-sectoral allocation. The regulation of groundwater extraction suffers a major gap, Brisco and Malik 2006. Apart from a limited Act for the Chennai metropolitan area, a Bill in Gujarat and the one recently passed by Maharastra for protecting rural water supply, none of the states in India have addressed groundwater rights. However, indirect attempts have been made for controlling groundwater extraction. These are, for example, through credit rationing by NABARD based on degree of aquifer development, curbing new power connection to bore wells, and electric power supply restrictions. The present environmental legislations and regulations are also weak in minimizing the environmental impact of groundwater utilization, Brisco and Malik 2006.

The Central Ground Water Board (CGWB) has prepared a model legislation for groundwater regulation, and this has been circulated to the state governments and undergone many revisions. The current version mainly emphasizes regulation and addresses management and overdraft regulations. These versions, however, contain no provision for ensuring participation of local population in management or regulation, Jeet 2005.

The establishment of tradable private property right in groundwater would be a major institutional reform. This could also empower communities to establish rights over the water they manage and address the issues of efficiency, equity and sustainability (Kumar 2003). However, bringing about reforms in water right would be a complex process. This is because such rights may not be always mutually exclusive (Saleth 1996). If appropriate legal, institutional and policy regime exist local user groups/ organizations can emerge in problem areas with support from external agencies such as NGOs. Some of them can help recognize the rights of individuals and communities over groundwater, and establish of tradable private property rights. The present institutional arrangements in India including central, state, and local institutions, and both formal and informal structures, do not enable comprehensive water allocation, planning and management.

Bold steps have been taken by many countries in face of similar challenges concerning groundwater ownership that India faces. In early 1980's the legislatures of the American arid states of Arizona and New Mexico replaced the common law rule of absolute ownership of groundwater with a government-administered permit system of groundwater extraction, (World Bank 1999a). So also the legislature of the Australian state of Victoria with the 1989 Water Act. In England and Wales, instead, government-administered licensing requirements were superimposed on the enjoyment of riparian rights in groundwater under the 1963 Water Act. The Spanish legislature passed legislation in 1985 whereby all hitherto private groundwater resources became the public property of the State. Italy's parliament passed legislation in 1994 vesting in the State all private water resources, including, in particular, groundwater. These legislations effectively curtailed such significant attributes of land ownership as the right to sink a well and to extract groundwater from beneath one's own land, (World Bank 1999a).

9. CONCLUDING OBSERVATIONS

Groundwater has rapidly emerged to occupy a dominant place in India's agriculture and food security. It has become the main source of growth in irrigated area and it now accounts for over 60 percent of the irrigated area in the country. It is estimated that now over 70 percent of India's food grain production comes from irrigated agriculture, in which groundwater plays a major role. Despite this huge significance, groundwater irrigation is heading for a crisis in India and needs urgent understanding and attention. The number of irrigation blocks considered overexploited is increasing at an alarming rate. The number of blocks in which, officially, the creation of wells must completely stop is scaling new heights every year. Yet, the sinking of wells continues rapidly. The way India will manage its groundwater resource in the future will clearly have very serious implications for the future growth and development of the agriculture sector in India, as well as the alleviation of poverty in India.

India has a large groundwater resource but its availability and status varies substantially from basin to basin, state to state and area to area. 40 percent of the groundwater resource is in the Ganga basin, and most others do not even cross 5 percent. Groundwater is found to be a superior source of irrigation compared to surface water and is associated with better yields, input use and profitability. This is mainly because it offers better control over water availability and use to the farmers. Increase in groundwater irrigation is closely associated with a reduction in the risk and variation in production.

Water is a state subject and groundwater is under the private regime in India. The rights to groundwater belong to the land owner. The rights to groundwater are transferred to anyone to whom the land is transferred. There is no limitation on how much groundwater a particular land owner can draw. This leads to a concentration of water ownership with the land owners in India and a lack of control over the extraction of water. Water markets can play an important role in reducing the inequalities between resource poor and rich farmers in the short run, but, in long run they may result in an adverse impact. The faster and excessive use of groundwater can cause an increase in the inequity among the farming community in the long run.

Some institutional provisions have been made to check over-exploitation of groundwater. This includes the withdrawal of institutional support for sinking new wells and a restriction on electric connection for irrigation purposes. These measures have proved to be largely ineffective to regulate the extraction of groundwater. Often, such measures are taken only when the situation reaches an alarming stage. When the zone is converted into a dark zone or over-exploited, only then are the proposed restrictions exercised.

Under the existing property rights groundwater is considered as an open resource in which farmers make private investment thinking that they have absolute rights to groundwater beneath their land, treating it as private property. This results in unchecked extraction of groundwater. In order to make the institutions more effective, there is an urgent need to define water rights. An integral approach at various levels is needed in general and through formal institutions in particular. Community-based action is also required for the efficient use of water resources in scarcity conditions through making effective the working of informal institutions. The establishment of tradable private property right in groundwater would be a major institutional reform. This could also empower communities to establish rights over the water they manage and address the issues of efficiency, equity and sustainability. Bold institutional and legislative steps have been taken by many countries in face of similar challenges concerning groundwater and such steps need to be taken up urgently in India for groundwater.

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