GOVERNMENT OF INDIA
MINISTRY OF WATER RESOURCES

NATIONAL GROUND WATER CONGRESS

Vigyan Bhawan, New Delhi
September 11, 2007

TECHNICAL PAPERS

Organised by :
CENTRAL GROUND WATER BOARD

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प्रधान मंत्री

Prime Minister

MESSAGE

It is a matter of great pleasure that the Ministry of Water Resources is organizing a "National Congress on Ground Water" to address various issues related to better governance of ground water as well as to facilitate the sharing of information and coordination with various agencies and stake-holders engaged in the programme of ground water development and management. I am happy that the Ministry has taken the initiative for organizing this event during 'Water Year 2007'. I am sure that national, regional and local issues related to ground water conservation and management and sustained development will be discussed during the Congress and a road map will be prepared for the benefit of different Government agencies, Industry Associations and Non-profit organizations to bring about a holistic perpective and a coordinated approach.

I wish the Congress all success

(Manmohan Singh)

New Delhi
September 6, 2007

प्रो० सैफुद्दीन सोज
PROF. SAIFUDDIN SOZ

जल संसाधन मंत्री
भारत
श्रम शक्ति भवन
रफी अहमद किदवई मार्ग
नई दिल्ली-110001
MINISTER OF WATER RESOURCES
INDIA
SHRAM SHAKTI BHAWAN
RAFI AHMED KIDWAI MARG
NEW DELHI-110001

MESSAGE

Ground Water is major source of water for drinking, industrial and agriculture needs. Our ground water resources are diminishing due to large scale use particularly for irrigated-agriculture. There is therefore urgency for sustained development and management of resources. One of the management option lie in water harvesting and recharging of ground water. The National Congress on Ground Water being organized by MoWR is expected to discuss various issues connected with sustainability of resource. I appeal one and all engaged in the development & use of ground water resource to pay particular attention to the aspect of protection and conservation of resource and join hands in promoting concept of augmentation and management of resources for developing clean drinking water supplies as well as ensuring food security.

I wish, Congress a great success in achieving desired goal of sustained development and management of resource.

Sd/-
Saifuddin Soz

जल वर्ष 2007 Water Year 2007

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

Tel. No. : 23714200, 23714663 (O), 23012786 (R), Fax : 23710804, e-mail : ssaif@sansad.nic.in

जय प्रकाश नारायण यादव
JAI PRAKASH NARAYAN YADAV

सत्यमेव जयते

जल संसाधन राज्य मंत्री
भारत सरकार
श्रम शक्ति भवन
नई दिल्ली-110001
**MINISTER OF STATE FOR
WATER RESOURCES
GOVERNMENT OF INDIA
SHRAM SHAKTI BHAWAN
NEW DELHI-110001**

MESSAGE

I am glad to know that a 'National Congress on Groundwater' is being organized by Ministry of Water Resources, Government of India in New Delhi on 11th September 2007.

Rapid developments in the water resources sector have been taking place in our country in the last few decades. Groundwater has a significant role in developing water supplies for various uses. However, the irrational and indiscriminate exploitation of groundwater resources in some parts of the country have resulted in various undesirable environmental fall out. The drying up of a large number of bore wells due to declining groundwater levels have had a direct impact on water supply for irrigation, industrial and domestic needs.

It has become necessary to ensure that the limited available groundwater resources are developed and managed in an efficient and judicious manner. There is also an urgent need for creating mass awareness among the people on the importance of water conservation and protection. The National Congress on Groundwater will surely pave the way for a concrete and realistic action plan for managing and augmenting our groundwater resources in a sustained manner.

I wish the Congress all success.

(Jai Prakash Narayan Yadav)

जल वर्ष 2007 — Water Year 2007

स्वच्छ सुरक्षित जल – सुन्दर खुशहाल कल

CONSERVE WATER - SAVE LIFE

National Ground Water Congress

Vigyan Bhawan, New Delhi.
September 11, 2007

PROGRAMME

	Time (hrs.)
Inaugural Function	**10.00-10.30**
Technical Session - I	**11.00-13.45**
No. of papers to be presented - 7	
1. Paper presentation - 15 minutes each (Total Duration : 1 hour 45 minutes)	11.00-12.45
2. Discussions : 1 hour	12.45-13.45
Technical Session - II	**14.30-16.45**
No. of papers to be presented - 5	
1. Paper presentation - 15 minutes (Total Duration : 75 minutes)	14.30-15.45
2. Discussions : 1 hour	15.45-16.45
Valedictory Function	**17.30-18.45**

Technical Session – I

Theme : "Awareness of Opportunities for Sustainable Management of Ground Water through Rain Water Harvesting and Water Conservation"

&

Theme : "Role of different Panchayati Raj Institutes, Agricultural Universities, Rural Institutes, Women Institutes and Private Sector in Ground Water Conservation and Sustainable and Equitable Use"

Panelist

1.	Dr. Kirit S. Parikh, Member, Planning Commission	**Chairman**
2.	Ms. Sunita Narayan, Director, CSE	**Member**
3.	Sh. B.M. Jha, Chairman, CGWB	**Member**
4.	Sh. Tushar Shah, IWMI	**Member**
5.	Sh. Ramaswami R. Ayer, Expert Water Resources, CPR.	**Member**

Technical Papers

1. *Deteriorating Ground Water Quality and its Implications on Rural Water Supply in India* by Sh. A. Bhattacharyya, Joint Secretary, Dept. of Drinking Water Supply, Ministry of Rural Development.

2. *Community Driven Decentralized Ground Water Management* by Sh. Rajendra Singh, Tarun Bharat Sangh, Alwar, Rajasthan.

3. *Artificial Recharge of Aquifers & Ground Water Regulation* by Dr. S.C.Dhiman, Member (SML), Central Ground Water Board.

4. *Role of Panchayat Women Leaders in Ground Water Conservation and Sustainable and Equitable Use* by Ms. Rita Sarin, Country Director, The Hunger Project, New Delhi.

5. *Role of Panchayats in Ground Water Management* by Dr. G. Palanithurai, Professor, Department of Political Science and Development Administration, Gandhigram Rural Institute (Deemed University), Gandhigram - 624 302, Tamil Nadu.

6. *Role of Agricultural Universities in Ground Water Conservation and Sustainable Use* by Prof. J.S. Samra, Chairman, National Rainfed Area Authority, New Delhi

7. *Role of Women in Ground Water Conservation, Sustainable and Equitable Use* by Dr. D. Janaki, Vice Chancellor, Mother Teresa Women's University, Kodaikanal, Tamil Nadu.

Technical Session – II

Theme : "More Crop and Income per Drop of Water"

Panelist

1.	Dr. M.S. Swaminathan,Hon'ble Member of Parliament.	**Chairman**
2.	Ms. Sunita Narayan, Director, CSE.	**Member**
3.	Sh. B.M. Jha, Chairman, CGWB.	**Member**
4.	Sh. Tushar Shah, IWMI.	**Member**
5.	Sh. Ramaswami R. Ayer, Expert Water Resources, CPR.	**Member**

Technical Papers

1. *Enhancing Water Productivity in Arid zones of Rajasthan* by Dr. Pratap Narain, Vice Chancellor, Rajasthan Agriculture University, Bikaner, Rajasthan.

2. *More Crop Income per Drop of Water in Gujarat* by Prof. M. C. Varshney, Vice Chancellor, Anand Agricultural University, Anand.

3. *Water Use and Enhancement of Productivity towards Optimised Benefits from Every Drop of Water in Kashmir* by Prof. Anwar Alam, Vice Chancellor, Sher-e-Kashmir University of Agricultural Sciences and Technology of Kashmir, Srinagar (J&K).

4. *More Crop and Income Per Drop of Water – A Status Report in respect of West Bengal* by Prof. S. Mallick, HOD, Bidhan Chandra Krishi Viswavidyalay, Nadia.

5. *Implementable Technologies on More Crop and Income per Drop of Water* by Dr. B. Bhaskar Reddy, Acharya NG Ranga Agricultural University, Rajendranagar, Hyderabad.

NATIONAL GROUND WATER CONGRESS

Advisory Committee

1. Prof. M.S. Swaminathan, Hon'ble Member of Parliament	-	Chairman
2. Chairman, Central Water Commission	-	Member
3. Additional Secretary (WR), Ministry of Water Resources	-	Member
4. Chairman, Central Ground Water Board	-	Member Secretary
5. Joint Secretary & FA, Ministry of Water Resources	-	Member
6. Commissioner(PP), Ministry of Water Resources	-	Member

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1. Chairman, Central Ground Water Board	-	Chairman
2. Member (WP&P), Central Water Commission	-	Member
3. Joint Secretary (A), Ministry of Water Resources	-	Member
4. Joint Secretary & FA, Ministry of Water Resources	-	Member
5. Commissioner (PP), Ministry of Water Resources	-	Member
6. Commissioner (GW), Ministry of Water Resources	-	Member
7. Member (SAM), Central Ground Water Board	-	Member Secretary

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1. Additional Secretary (WR), Ministry of Water Resources	-	Chairman
2. Chairman, Central Ground Water Board.	-	Member
3. Joint Secretary (A), Ministry of Water Resources	-	Member
4. Commissioner (GW), Ministry of Water Resources	-	Member
5. Director (A), Ministry of Water Resources	-	Member
6. Director (C&PPP), Ministry of Water Resources	-	Member
7. Consultant, Ministry of Water Resources	-	Member
8. Director (Administration), Central Ground Water Board	-	Member Secretary

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CONTENTS

Technical Papers

Theme : ***"Awareness of Opportunities for Sustainable Management of Ground Water through Rain Water Harvesting and Water Conservation"***

Theme : "Role of different Panchayati Raj Institute, Agricultural Universities, Rural Institutes, Women Institute and Private Sectors in Ground Water Conservation and Sustainable and Equitable Use"

Theme: Awareness of Opportunities for Sustainable Management of Ground Water through Rain Water Harvesting and Water Conservation

GROUND WATER DEVELOPMENT AND MANAGEMENT STRATEGIES IN INDIA

B.M.Jha*

Introduction

Ground water resources play a vital role in sustaining the livelihoods of many countries in the world. Its ubiquitous occurrence, reliability and availability in all seasons have made it the primary buffer against drought, playing a pivotal role in ensuring the food security at all levels. More than half the world's population is considered to depend on ground water for its survival (UNESCO, 1992). The alarming depletion of ground water resources in the last few decades has made it the focus of attention of administrators, planners and policy makers all over the world, making it one of the most hotly discussed topics today.

Ground water has an important role in meeting the water requirements of agriculture, industrial and domestic sectors in India. Its importance as a precious natural resource in the Indian context can be gauged from the fact that more than 85 percent of India's rural domestic water requirements, 50 percent of its urban water requirements and more than 50 percent of its irrigation requirements are being met from ground water resources. The increasing dependence on ground water as a reliable source of water has resulted in its large-scale and often indiscriminate development in various parts of the country without due regard to the recharging of aquifers and other environmental factors. The unplanned and unscientific development of ground water resources, mostly driven by individual initiatives, has led to an increasing stress on the available resources. The adverse impacts can be observed in the form of long-term decline of ground water levels, de-saturation of aquifer zones, increased energy consumption for lifting water from progressively deeper levels and quality deterioration due to saline water intrusion in coastal areas in different parts of the country. On the other hand, there are areas in the country, where ground water development is still low-key in spite of the availability of sufficient resources. The canal command areas suffer from problems of water logging and soil salinity due to the gradual rise in ground water levels.

In view of the factors mentioned above, there is a need for strategies aimed at scientific and sustainable management of the available ground water resources in the country to avert the looming water crisis. Such a management strategy should consider various aspects such as the availability of ground water resources and their development prospects. These are described in the following sections.

Hydrogeological Setup

India is a vast country with a highly diversified hydrogeologic set-up. The ground water behaviour in the Indian sub-continent is highly complicated due to the occurrence of diversified geological formations with considerable lithological and chronological variations, complex tectonic framework, climatological dissimilarities and various hydrochemical conditions. Studies carried out over the years have revealed that aquifer groups in alluvial / soft rocks often transcend the surface basin boundaries. Broadly two group of water bearing rock formations have been identified depending on characteristically different hydraulics properties, viz. Porous formations which can be further classified into unconsolidated and semi consolidated formations

*Chairman, Central Ground Water Board.

having primary porosity and Fissured formations or Consolidated formations which have mostly secondary or derived porosity (Fig-1).

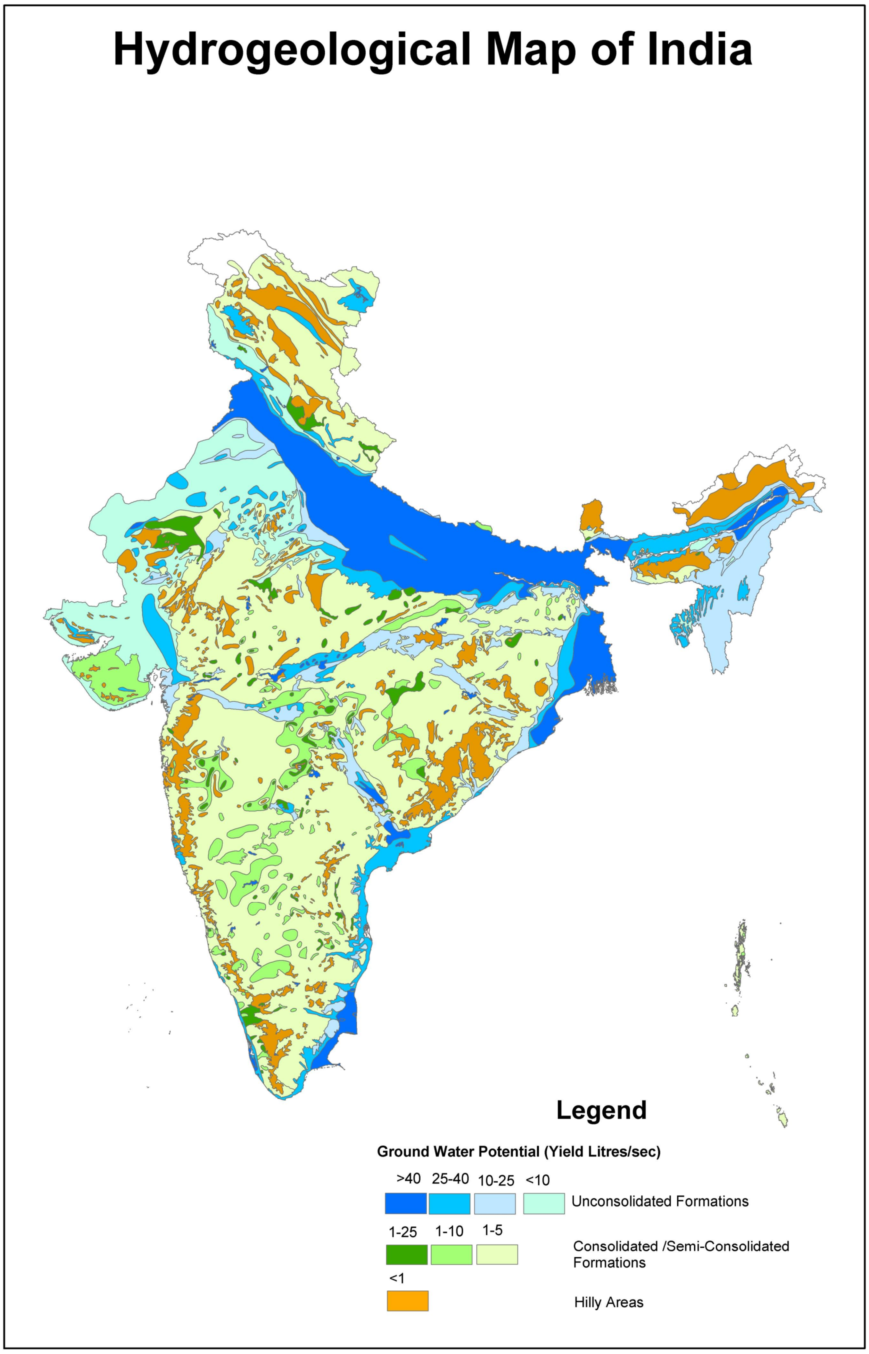

Fig. 1: Hydrogeological Map of India.

Physiographic and geomorphologic set up plays a vital role in the occurrence and distribution of ground water. An attempt has been made to establish broad relationships between different physiographic units and occurrence and movement of ground water. The entire country has been broadly divided into five distinct regions considering the characteristic physiographic features as well as occurrence and distribution of ground water.

i) *Northern Mountainous Terrain and Hilly areas*: The highly rugged mountainous terrain in the Himalayan region in the northern part of the country, extending from Kashmir to Arunachal Pradesh, is characterized by steep slopes and high runoff. This region is occupied by varied rock types including granites, slate, sandstone and limestone ranging in age from Paleozoic to Cenozoic. The yield potential of valley fills ranges from 1 to 40 lps. Though this area offers very little scope for ground water storage, the valley fills function as underflow conduit and act as the major source of recharge for the vast Indo-Gangetic and Brahmaputra alluvial plains.

ii) *Indo-Gangetic-Brahmaputra Alluvial Plains*: This region encompasses an area of about 850,000 sq km covering states of Punjab, Haryana, Uttar Pradesh, Bihar, Assam and West Bengal, , which is more than one fourth of country's area and comprises the vast plains of Ganges and Brahmaputra rivers underlain by thick pile of sediments of Tertiary and Qarternary age. The sediments have been deposited in a foredeep or crustal down –buckle. The thickness of the sediments decreases from north to south. At places the thickness of the alluvium exceeds 1000 m. This vast and thick alluvial fill form the most potential and productive ground water reservoir in the country. These are characterized by regionally extensive and highly productive multi-aquifer systems. In the present scenario, ground water development in this region is low key except the western most part in the states of Haryana and Punjab. The deeper aquifers available in these areas offer good scope for further exploitation of ground water with suitable measures. In Indo-Gangetic- Brahmaputra plain, the deeper wells have yields ranging from 25-50 lps.

iii) *Peninsular Shield Areas*: These are located south of Indo-Gangetic-Brahmaputra plains and consist mostly of consolidated sedimentary rocks, Deccan Trap basalts and crystalline rocks in the states of Karnataka, Maharashtra, M.P, Kerala and Tamil Nadu. Occurrence and movement of ground water in these formations are restricted to weathered residuum and interconnected fractures at deeper levels and they have limited ground water potential. The rocks are commonly weathered to a depth of 30 m under the tropical conditions in central and southern part of the peninsular region. Ground water occurs mainly in the weathered and fractured zones of rocks, within depth of less than 50 m, occasionally down to 100 m, and rarely below this depth. Locally deep circulation of ground water is indicated, as instanced by striking solution cavities or deeper water bearing fractures. Ground water development is largely through dug wells. The valley fills in this region are often dependable sources of water supply. The yield of wells tapping deeper fractured zones in hard rocks varies from 2-10 lps.

iv) *Coastal Areas*: Coastal areas have a thick cover of alluvial deposits of Pleistocene to Recent and form potential multi-aquifer systems covering states of Gujarat, Kerala, West Bengal, Tamil Nadu, Andhra Pradesh and Orissa. However, inherent quality problems and the risk of seawater ingress impose severe constrains in the development of these aquifers. In addition, ground water development in these areas is highly vulnerable to up-coning of saline water. The yield of the wells varies from 20-25 lps.

v) *Cenozoic Fault Basin and Low Rainfall Areas*: This region has been grouped separately owing to its peculiarity in terms of presence of three discrete fault basins, the Narmada, the Purna and Tapti valleys, all of which contain extensive valley fill deposits. The fill ranges in thickness from about 50 to 150 m. The aquifer systems in arid and semi-arid tracts of this region in parts of Rajasthan and Gujarat receive negligible recharge from the scanty rains and the ground water occurrence in these areas is restricted to deep aquifer systems tapping fossil water. For example, in parts of Purna valley the ground water is extensively saline and unfit for drinking and other purposes. The yield potential of the wells varies from 1-10 lps.

Ground Water Resources Estimation

Rainfall is the major source of ground water recharge in India, which is supplemented by other sources such as recharge from canals, irrigated fields and surface water bodies. A major part of the development of ground water resources takes place from the upper unconfined aquifers, which is also the active recharge zone and holds the dynamic ground water resource. The dynamic ground water resource in the active recharge zone in the country has been assessed by Central Ground Water Board in association with the concerned State Government authorities and the National Bank for Agricultural and Rural Development (NABARD). The assessment was carried out with Block/Mandal/Taluka/Watershed as the assessment unit and as per norms recommended by the Ground Water Estimation Committee (GEC)-1997. As per the latest estimates of 2004, the annual replenishable ground water resource in this zone has been estimated as 433 Billion Cubic Meters (BCM), out of which 399 BCM is considered to be available for development for various uses. The remainder of 34 BCM is set aside for natural discharge during non-monsoon period for maintaining flows in springs, rivers and streams. The state-wise ground water resources availability, utilization, stage of development and categorization is given in Table-1. The ground water resources availability and utilization in India is pictorially presented in Figure 2.

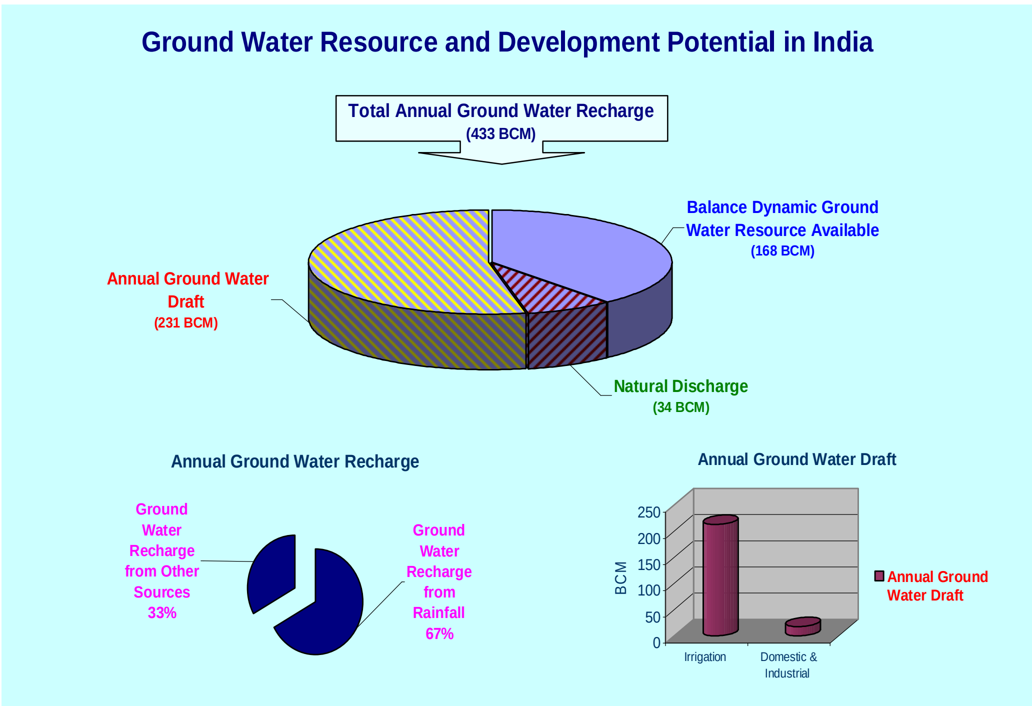

Fig.2: Ground water Resources Availability & Utilization in India

In addition to the resources available in the zone of water level fluctuation, extensive ground water resources have been proven to occur in the confined aquifers in the Ganga-Brahmaputra alluvial plains, coastal areas and deltaic tracts. These aquifers have their recharge zones in the upper reaches of the basins. The resources in these deep-seated aquifers are termed ‘In-storage ground water resources’. In alluvial areas, these resources are normally renewable over long periods of time, except in cases like the ‘Lathi’ aquifers in Rajasthan, which comprise essentially non-renewable fossil water. Tentative estimates put the total quantum of in-storage ground water resources at about 10,800 BCM

Table.1. State-wise Ground Water Resources Availability, Utilization and Stage of Development in India (in BCM)

Sl. No.	States / Union Territories	Annual Replenishable Ground Water Resources	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability	Annual Ground Water Draft	Stage of Ground Water Development (%)	Categorization of assessment Units (numbers)	
							Over-exploited	Critical
1	2	3	4	5	6	7	8	9
	States							
1	Andhra Pradesh	36.5	3.55	32.95	14.9	45	219	77
2	Arunachal Pradesh	2.56	0.26	2.3	0.0008	0.04	0	0
3	Assam	27.23	2.34	24.89	5.44	22	0	0
4	Bihar	29.19	1.77	27.42	10.77	39	0	0
5	Chhattisgarh	14.93	1.25	13.68	2.8	20	0	0
6	Delhi	0.3	0.02	0.28	0.48	170	7	0
7	Goa	0.28	0.02	0.27	0.07	27	0	0
8	Gujarat	15.81	0.79	15.02	11.49	76	31	12
9	Haryana	9.31	0.68	8.63	9.45	109	55	11
10	Himachal Pradesh	0.43	0.04	0.39	0.12	30	0	0
11	Jammu & Kashmir	2.7	0.27	2.43	0.33	14	0	0
12	Jharkhand	5.58	0.33	5.25	1.09	21	0	0
13	Karnataka	15.93	0.63	15.3	10.71	70	65	3
14	Kerala	6.84	0.61	6.23	2.92	47	5	15
15	Madhya Pradesh	37.19	1.86	35.33	17.12	48	24	5
16	Maharashtra	32.96	1.75	31.21	15.09	48	7	1
17	Manipur	0.38	0.04	0.34	0.002	0.65	0	0
18	Meghalaya	1.15	0.12	1.04	0.002	0.18	0	0
19	Mizoram	0.04	0.004	0.04	0.0004	0.9	0	0
20	Nagaland	0.36	0.04	0.32	0.009	3	0	0
21	Orissa	23.09	2.08	21.01	3.85	18	0	0
22	Punjab	23.78	2.33	21.44	31.16	145	103	5
23	Rajasthan	11.56	1.18	10.38	12.99	125	140	50
24	Sikkim	0.08	0	0.08	0.01	16	0	0
25	Tamil Nadu	23.07	2.31	20.76	17.65	85	142	33
26	Tripura	2.19	0.22	1.97	0.17	9	0	0
27	Uttar Pradesh	76.35	6.17	70.18	48.78	70	37	13
28	Uttarakhand	2.27	0.17	2.1	1.39	66	2	0

Sl. No.	States / Union Territories	Annual Replenishable Ground Water Resources	Natural Discharge during non-monsoon season	Net Annual Ground Water Availability	Annual Ground Water Draft	Stage of Ground Water Development (%)	Categorization of assessment Units (numbers)	
							Over-exploited	Critical
1	2	3	4	5	6	7	8	9
29	West Bengal	30.36	2.9	27.46	11.65	42	0	1
	Total States	**432.42**	**33.73**	**398.7**	**230.4**	**58**	**837**	**226**
	Union Territories							
1	Andaman & Nicobar	0.33	0.005	0.32	0.01	4	0	0
2	Chandigarh	0.023	0.002	0.02	0	0	0	0
3	Dadra & Nagar Haveli	0.063	0.003	0.06	0.009	14	0	0
4	Daman & Diu	0.009	0.0004	0.008	0.009	107	1	0
5	Lakshadweep	0.012	0.009	0.004	0.002	63	0	0
6	Pondicherry	0.16	0.016	0.144	0.151	105	1	0
	Total UTs	**0.597**	**0.036**	**0.556**	**0.181**	**33**	2	0
	Grand Total	**433.02**	**33.77**	**399.25**	**230.6**	**58**	**839**	**226**

Ground Water Development Status

Growth of Ground Water Abstraction Structures

Ground water extraction for various uses and evapotranspiration from shallow water table areas constitute the major components of ground water draft. In general, the irrigation sector remains the main consumer of ground water. Data available from the census of minor irrigation structures (Table.2) indicates a three-fold increase in the number of ground water abstraction structures from about 6 million during 1982-83 to about 18.5 million during 2001-02 (Fig.3).

Table.2 Growth of Ground Water Abstraction Structures in India (1982-2001)

Type of Structure	Number of Structures			
	1982-1983	**1986-1987**	**1993-1994**	**2000-2001**
Dug well	5384627	6707289	7354905	9617381
Shallow Tube well	459853	1945292	3944724	8355692
Deep Tube well	31429	98684	227070	530194

It is also seen that the growth has been more pronounced in shallow and deep tube wells (17 to 18 times) when compared to dug wells (about 2 times). This shift is probably the combined result of deepening ground water levels and advances in drilling and pumping technology. The ground water draft for the country as a whole has been estimated as 231 BCM, about 92 percent of which is utilized for irrigation and the remaining 8 percent for domestic uses. Hence, the stage of ground water development, computed as the ratio of annual ground water draft to net annual

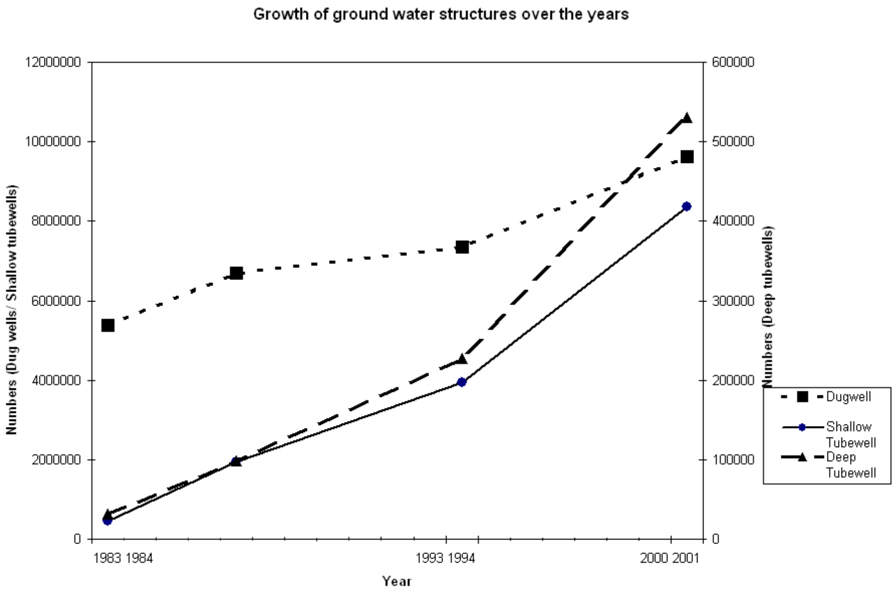

Fig.3 Growth of Ground Water Abstraction Structures in India
(Source: Minor Irrigation Census, 2001)

ground water availability, works out as about 58 percent for the country as a whole. However, the development of ground water in the country is highly uneven and shows considerable variations from place to place.

Categorization of Assessment Units

As part of the resource estimation as per GEC -1997 norms, the assessment units have been categorized based on the stage of ground water development and long term declining trend of ground water levels. As per the assessment, out of the total of 5723 assessment units in the country, ground water development was found to exceed more than 100 % of the natural replenishment in 839 units, which have been categorized as 'Over-exploited'. Ground water development was found to be to the extent of 90 to 100 percent of the utilizable resources in 226 assessment units, which have been categorized as 'Critical'. The categorization of assessment units for the country is shown in Fig.4.

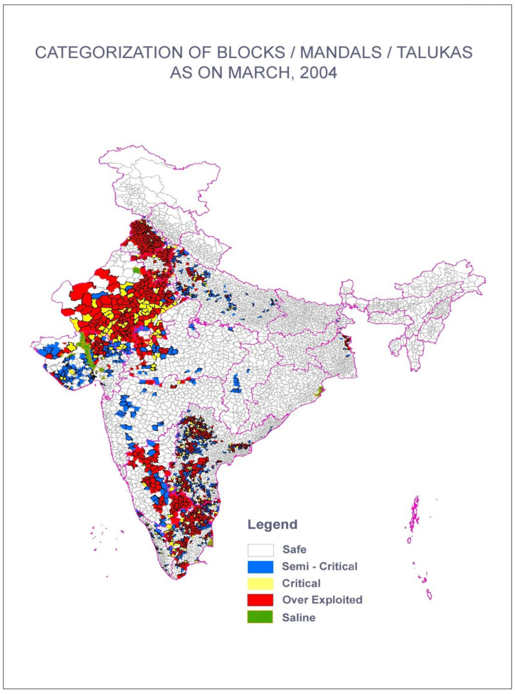

Fig-4 Categorization of Assessment Units Based on the Stage of Ground Water Development in India (As on March 2004)

The variability in the distribution of ground water resource and its utilization is clearly seen in the data provided in Table -1. It is seen that the stage of ground water development ranges from 0.04 percent in Arunachal Pradesh to 170 percent in Delhi. The states of Andhra Pradesh, Tamil Nadu, Rajasthan and Punjab account for more than 70 percent of the total number of overexploited assessment units in the country as a whole.

Rainfall Variations

The rainfall pattern of the country is evident form the Isohyetal map (Fig-5) of the country showing the annual normal rainfall.

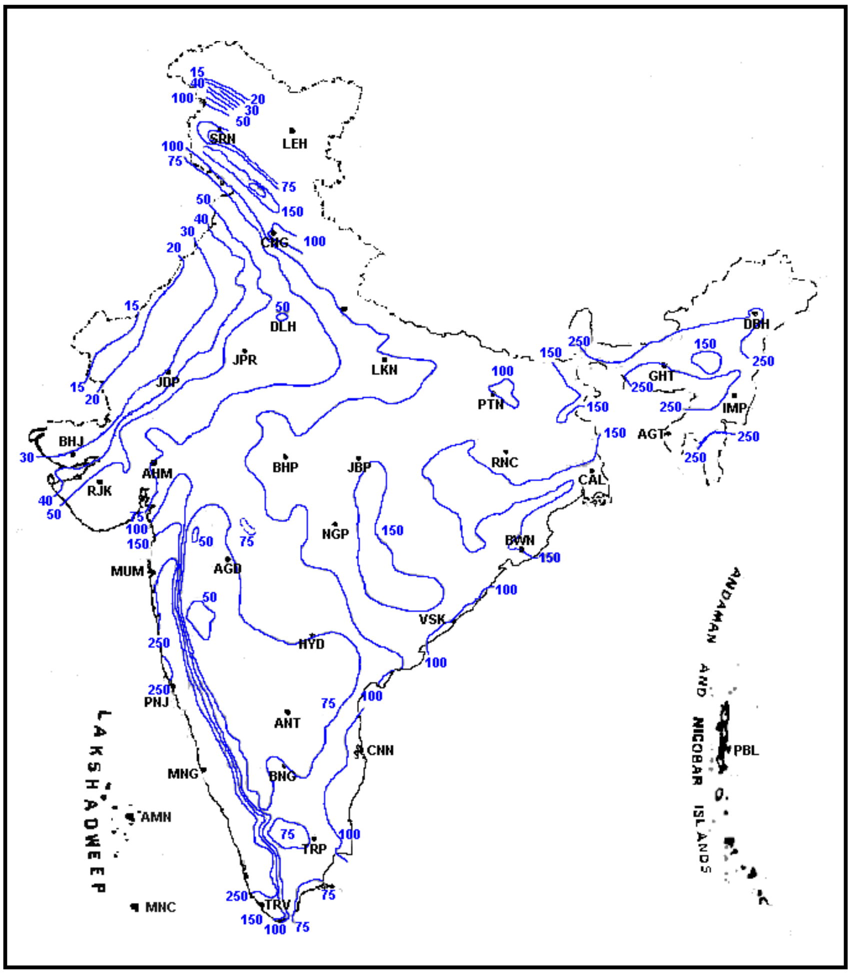

Fig- 5 Map showing the Annual Normal Rainfall (in cm.)

In India, rainfall is unevenly distributed spatially and temporally. The average rainfall of the country is around 117 cm. From the perusal of isoheytal map it can be observed that the rainfall is below 75 cm in the north western part of the country covering major part of the states of Rajasthan, Gujarat, Haryana, and in the southern part, in the states of Karnataka and Tamil Nadu. A review of annual ground water availability, contribution from monsoon rainfall recharge and annual ground water draft in different states falling under overexploited category and the rainfall distribution in space brings a paradoxical situation in the sense that, withdrawal of ground water is not solely responsible for declining trends, the scantly and low rainfall resulting in meager monsoon recharge is equally important. Majority of the ground water stress areas categorized as overexploited and critical units also lies in these states.

The variations in depth to ground water level in the country during pre-monsoon and post monsoon period is shown in Fig-6a & 6b.

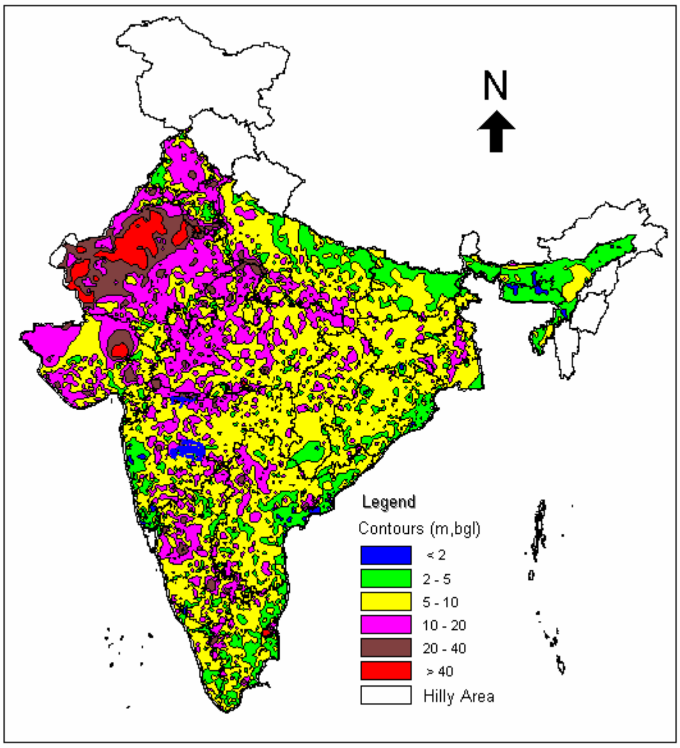

Fig-6a Map Showing Depth to Water Level (Pre-Monsoon, 2006)

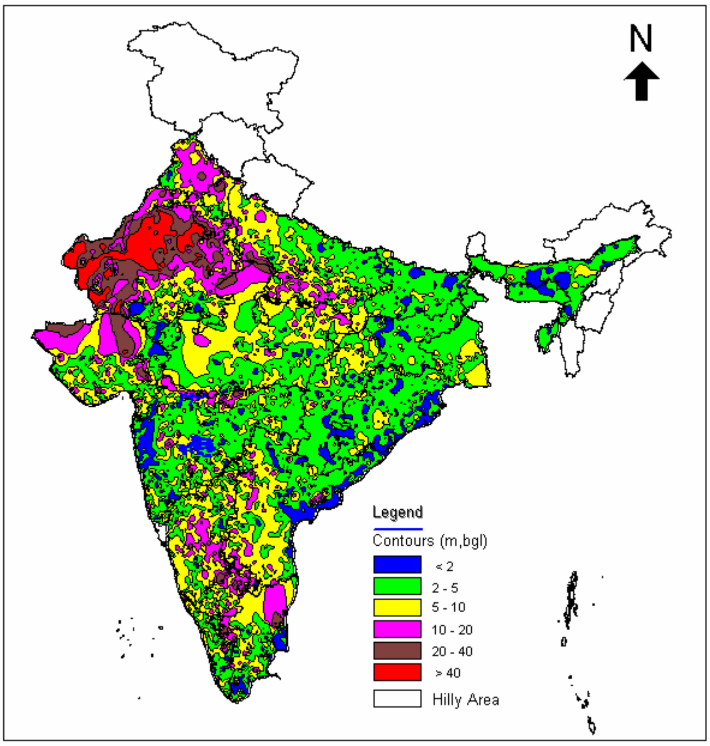

Fig-6b Map Showing Depth to Water Level (Post-Monsoon, 2006)

It has been observed that deepest water levels of 40 m and above are common in the western part of the country which is also the zone of low rainfall resulting in meager natural ground water recharge.
Quality of Ground water

As regards quality, the ground water in the major part of the country is potable and suitable for irrigation and industrial uses, except in few areas where they have been rendered non-potable due to the presence of geogenic contaminants such as Fluoride, Iron, Arsenic etc. in excess of limits prescribed for human consumption. These include Inland salinity problems in the arid and semi-arid regions of Rajasthan, Haryana, Punjab and Gujarat, arsenic hazards in Gangetic alluvial belt, iron contamination in Brahmaputra and Kosi river basins, fluoride problems in hard rock areas of Andhra Pradesh, Tamil Nadu, Madhya Pradesh, Karnataka etc. Excessive withdrawal of ground water may also lead to salinity ingress and consequent ground water contamination as experienced in coastal areas of Mangrol-Chorwad tract and coastal Saurashtra of Gujarat and in Minjur area south of Chennai in Tamil Nadu. Ground water pollution due to domestic and industrial effluents and excessive application of fertilizers and pesticides are also observed, mostly as localized phenomenon.

Various issues discussed above bring the complexities involved in managing the ground water resources of the country. There is an urgent need to prepare a vision document focusing the efficient measures for ground water management to combat the emerging problems of water scarcity. An attempt has been made in this direction.

Management of Ground Water Resources

Management of ground water resources in a country as vast and diverse as India is an extremely complex proposition as it deals with the interactions between the human society and the physical environment. The highly uneven distribution of ground water availability and its utilization indicates that no single management strategy can be adopted for the country as a whole. On the other hand, each situation demands a solution which takes into account the geomorphic set-up, climatic, hydrologic and hydrogeologic settings, ground water availability, water utilization pattern for various sectors and the socio-economic set-up of the region.

Any strategy for scientific management of ground water resources involves a combination of A) Supply side measures aimed at increasing extraction of ground water depending on its availability and B) Demand side measures aimed at controlling, protecting and conserving available resources. Various options falling under these categories are described in detail in the following sections.

Supply Side Measures

As already mentioned, these measures are aimed at increasing the extraction of ground water depending on its availability, taking the environmental, social and economic factors into consideration. These are also known as ‘structural measures’, which involves scientific development and augmentation of ground water resource. Development of available ground water resources through suitable means and augmentation through rainwater harvesting and artificial recharge fall under this category. For an effective supply-side management, it is imperative to have full knowledge of the hydrologic and hydrogeologic controls that govern the yields of aquifers and behavior of ground water levels under abstraction stress. Interaction of surface and ground water and changes in flow and recharge rates are also important considerations in this regard.

Scientific Development of Ground Water Resources

Ground Water Development in Alluvial Plains

Scientific studies have proven that ample reserve of ground water is available in the areas underlain by Indo-Gangetic and Brahmaputra alluvial plains in the northern and northeastern parts of the country. Coincidently, the ground water development in these areas are sub-optimal, in spite of the availability of resources, and offers considerable scope for ground water development in future. In addition to the sufficient availability of dynamic ground water resources in the phreatic zone, there is a vast in-storage ground water resource in the deeper zones i.e. below the zone of ground water fluctuation. The estimates of in-storage ground water resources on pro-rata basis down to a depth of 400 m works out to be 10812 BCM , out of which nearly 10633 BCM is available in the areas occupied by alluvial and unconsolidated formations. Surprisingly the three major States occupying the Alluvial plains i.e. Uttar Pradesh, Bihar and West Bengal , has a share of the in storage ground water resources to the tune of 7652 BCM which is more than 70% of the total.

Fragmented land holdings, poor socio-economic status, poor infrastructure facilities, and lack of knowledge of modern technologies are some of the reasons for the under-utilization of ground water resources in these areas, in spite of the growing need for boosting agricultural production. In this context, there is an urgent need to explore various options for optimal utilization of these resources. One of the management measures could be to adopt the concept of ***Virtual water***. Virtual water is defined as water embedded in commodities. It is said that the largest exported commodity in the world is "Water", which is in terms of virtual water contained in the food grains. As a thumb rule, a grain of crop transpires about 1 cubic meter of water in order to produce 1 kilogram of grain. Thus, exporting or importing 1 kilogram of grain is approximately equivalent to exporting 1 cubic meter of water. The best example of virtual water in Indian context can be thought in terms of producing fodder in the water surplus areas of Indo-Gangetic plains and transported to the water stressed areas of Gujarat, Rajasthan, Punjab etc. This way, water used for fodder production in these states can be reduced and water saved can be fruitfully utilized for other priority sectors.

At the same time, there is an urgent need for Government financed schemes for planned scientific ground water development in these areas. Such schemes should be implemented, considering the socio-economic conditions of the beneficiaries and should be managed through community participation functioning under the broader spirit of cooperative movement.

Ground Water Development in Coastal Areas

Many parts of the coastal areas of India have thick deposits of sediments ranging in age from Pleistocene to recent, which have given rise to multi-aquifer systems of good potential. There is considerable scope for development of ground water from such aquifer systems. However, development of ground water from such aquifers needs to be done with caution and care should be taken to ensure that over-exploitation of resources does not lead to saline water intrusion. Large diameter dug wells, filter point wells and shallow tube wells are ground water abstraction structures best suited for such aquifers. Radial wells and infiltration galleries can also be constructed in areas where the requirement of water is large. As the multi-aquifer systems in coastal areas are likely to have all possible dispositions of fresh and saline waters, it is necessary to take up detailed studies to establish the saline–fresh water interface and establish the dynamics of discharge of ground water to sea. This will ensure the implementation of ground water development plans. Further, sanctuary wells need to be constructed in hydrogeologically suitable areas to meet the water requirement during unforeseen situations like Cyclonic disasters, Tsunamis etc.

Ground Water Development in Hard Rock Area

The hard rock areas are characterized by considerable heterogeneity and anisotropy and the aquifers are normally discontinuous and of limited ground water potential. In spite of their limited potential, these aquifers play an important role in meeting the drinking, agricultural and industrial needs in the peninsular shield areas of the country. In spite of the relatively high stage of ground water utilization in the hard rock terrain, there is further scope for development in many States including Kerala, Tamil Nadu, Karnataka and Maharashtra. Any scheme for further ground water development in such areas should be preceded by detailed studies for identification of area suitable for ground water development. Modern technologies in the fields of remote sensing and Geographical Information Systems (GIS), coupled with conventional hydrological and hydrogeological surveys can be used for demarcating areas suitable for further ground water development in such terrain. Shallow and deep buried pediments, valley fills, bazada zones and flood plains of streams offer ideal locales for construction dug wells and dug cum bore wells, whereas intersection of lineaments are ideal for construction of bore wells. However, there is a need to restrict the development from such aquifers within their recharging capabilities to ensure their long-term sustainability.

Ground Water Development in Water-logged Areas

Water-logging and soil salinity problems, resulting from gradual rise of ground water levels, are observed in many canal command areas due to the implementation of surface water irrigation schemes without due regard to environmental considerations. As per the assessment made by the Working Group on Problem Identification with Suggested Remedial Measures (1991), about 2.46 million hectare of land under surface water irrigation projects in the country is either water-logged or under threat of it. Such areas offer good scope for further ground water development as the shallow water table in such areas can be lowered down to six meters or more without any undesirable environmental consequences. The problems related to inferior quality of water in such areas can be solved by mixing them with the canal waters available. Judicious development through integrated use of surface and ground water resources can greatly reduce the menace of water-logging and salinity in canal irrigated areas. Such efforts will also be in line with the directives of National Water Policy which states that surface and ground water should be viewed as an integrated resource and should be developed conjunctively in coordinated manner and their use should be envisaged right from the project planning stage.

Ground Water Development from Deep Aquifers

The stage of ground water development is rather high in the States of Haryana, Punjab and Rajasthan and a large number of over-exploited and critical assessment units fall in these states. Studies by CGWB in the Indo-Gangetic basin in Punjab, Haryana, Uttar Pradesh, Bihar and West Bengal have revealed the existence of deep-seated aquifers storing voluminous quantity of ground water. Fresh ground water has been reported down to a depth of about 700 m in Uttar Pradesh. Exploratory studies carried out by ONGC in the Gangetic alluvium indicated existence of fresh ground water at more than 1000 m depth. Similarly, free flow of ground water due to artesian conditions exists in some areas like Tarai and sub-Tarai belt of Uttar Pradesh and Bihar. As no energy is required for extraction of ground water from such aquifers, development of ground water from these auto-flow zones is both economically viable and eco-friendly.

Development of Flood Plain Aquifers

Flood plains of rivers are normally good repositories of ground water and offers excellent scope for development of ground water. Ground water levels in these tracts are mostly shallow, leaving little room for accommodating the monsoon recharge, a major portion of which flows down to the river as surface (flood) and sub-surface runoff. A planned management of water resource in these tracts can capture the surplus monsoon runoff, which otherwise goes waste. The strategy involves controlled withdrawal of ground water from the flood plains during non-monsoon season to create additional space in the unsaturated zone for subsequent recharge/infiltration during rainy season.

There are two distinct conditions as regards induced recharge from the river/stream to ground water aquifer. The first condition involves setting up a hydraulic connection between the aquifer and the river as recharge boundary due to heavy exploitation of ground water and expansion of cone of depression. This condition is common in case of perennial rivers and leads to changes in river flow conditions in the down stream. The hydraulic connection between the river and the aquifer ceases as soon as pumping is stopped.

The second scenario is more common in case of rivers having intermittent flows; the loose sediments in the flood plains are more or less saturated resulting into shallower ground water levels. The heavy withdrawal of such flood plain aquifers during the non-monsoon creates ample space in the ground water reservoir which gets recharged by the river during the flood season. In absence of such created space the river water would overflow. This condition is more prevalent in Indian scenario and provides opportunity for augmentation of ground water reservoir through induced recharge.

A study in this regard was taken up in northern part of Yamuna flood plain area in Delhi (Fig.7) wherein Central Ground Water Board constructed 95 tube wells in Palla Sector in the depth range of 38-50 m for Delhi Jal Board, the domestic water supply agency of the State. On the basis of scientific studies, it was found out that nearly 30 MGD of water can be safely drawn from these tube wells during monsoon and non-monsoon seasons to meet drinking water requirements of National Capital Territory, Delhi. In this process, a part of flood water (rejected recharge) is utilized to augment sub-surface storage during monsoon.

The experience of Yamuna flood plains in Delhi has shown the scope of enhancing ground water recharge by pumping to lower the water table ahead of the rainy season and thus creating more space for the flood water to percolate. The concept can be implemented in similar situations in different parts of the country after carrying out detailed study on the hydrodynamics of the flood plain zones involving stream-aquifer interaction.

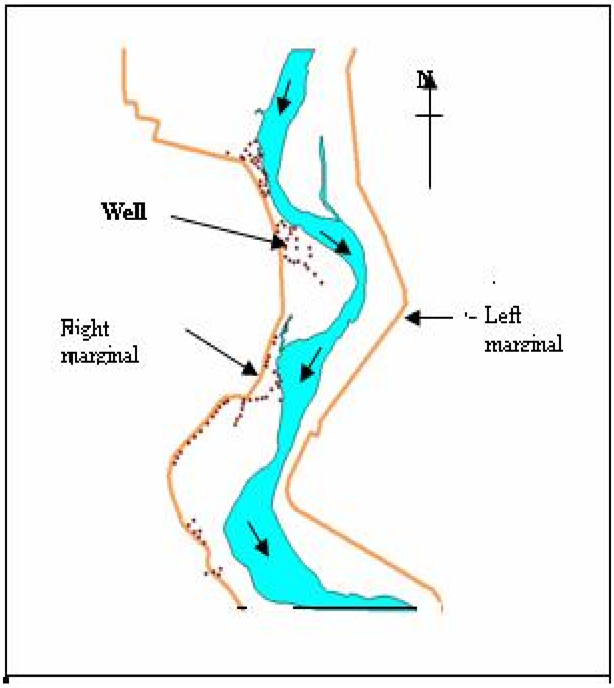

Fig. 7: Ground Water Development in Yamuna Flood Plain, Palla, Delhi

Augmentation of Ground Water Resources

Rainwater Harvesting and Artificial Recharge to Ground Water

Rainwater harvesting and artificial recharge have now been accepted worldwide as cost-effective methods for augmenting ground water resources and for arresting/reversing the declining trends of ground water levels. Artificial recharge techniques are highly site-specific. Suitability of area in terms of availability of sub-surface storage space and availability of surplus monsoon run-off are important considerations for successful implementation of artificial recharge schemes.

Rainwater harvesting and artificial recharge schemes implemented by various organizations in the country including Central Ground Water Board have shown encouraging results in terms of augmentation of ground water recharge, check in rate of decline of ground water levels and reduction of surplus run off. Increased sustainability of existing abstraction structures, increase in irrigation potential, revival of springs, soil conservation through increase in soil moisture and improvement in ground water quality are among other benefits of the schemes. In the coastal tracts, tidal regulators, constructed to impound the fresh water upstream and enhance the natural recharge are effective in controlling salinity ingress. Pilot schemes implemented by CGWB during VIII and IX plan periods have indicated the efficacy of Percolation tanks, check dams, recharge shafts and sub-surface barriers in augmenting ground water resources in the hard rock areas of Andhra Pradesh, Karnataka, Kerala, Madhya Pradesh, Maharashtra and Tamil Nadu. Recharge trench, recharge shaft and recharge tube wells are found to be the most suitable structures for recharge augmentation in alluvial areas. Schemes implemented in Haryana, Punjab, Delhi and Chandigarh have shown rise in water level in the range 0.25 to 0.70 m.

Experience gained from pilot artificial recharge schemes implemented by Central Ground Water Board in different hydrogeological settings in the country has indicated that optimal benefits can be achieved when various recharge structures are constructed at suitable locations in complete hydrological units such as watersheds, sub-basins etc. The percolation tank with recharge shaft suited to rural areas is constructed at Randan Khedi, District, Dewas, M.P is shown in Fig 8, similarly, a typical roof top rain water harvesting and ground water recharge through dug well suiting to urban areas constructed at Musa Kheri, Indore town is shown in Fig.9.

Central Ground Water Board has also carried out studies for demarcating areas of long-term decline of ground water levels and for exploring the possibility of augmenting the ground water resources in these aquifers using available surplus monsoon runoff. An area of about 4.5 lakh sq km has been identified in the country where such augmentation measures are considered necessary. It has also been estimated that about 36 BCM of surplus monsoon runoff can be recharged into these aquifers annually (CGWB, 2002). Modification of natural movement of surface water into the aquifers through various structures like check dams, percolation ponds, recharge pits, shafts or wells are considered suitable in rural areas. On the other hand, roof-top rainwater harvesting, either for storage and direct use or for recharge into the aquifers is suited for urban habitations with its characteristic space constraints.

Regular and proper maintenance of structures is a necessary prerequisite for the success of any artificial recharge scheme. This can be ensured only through active participation of stake holders. At present, rainwater harvesting and artificial recharge schemes are mostly implemented through government and non-governmental initiatives. There is a need to shift the initiative from institutional endeavor and make it into a mass movement. Community based programmes on rain water harvesting and artificial recharge would inculcate a sense of responsibility among the stake holders, thereby enhancing the efficiency level of maintenance of the schemes.

Fig. 8 - Percolation Tank with Recharge Shaft at Randan Khedi, District, Dewas, M.P.

Fig 9 - Roof Top Rain Water Harvesting and Ground Water Recharge Through Dug Well at Musa Kheri, Indore Town, M.P.

Demand Side Measures

Apart from scientific development of available resources, proper ground water resources management requires to focus attention on the judicious utilization of the resources for ensuring their long-term sustainability. Ownership of ground water, need-based allocation and pricing of resources, involvement of stake holders in various aspects of planning, execution and monitoring of projects and effective implementation of regulatory measures wherever necessary are the important considerations with regard to demand side ground water management.

Ownership of Ground Water

Ownership is an important issue to be resolved before implementation of any strategy for managing ground water resources. In spite of the importance being given to ground water resources in our country, the legal position regarding ownership of ground water is still not very clear. The absolute ownership concept, embodied in the Indian Easement Act 1882, has paved way for unlimited extraction of ground water by the land owners. One of the consequences of this law is the ownership of all ground water by the land owners, while the landless laborers and poor tribals are left out. The over-exploitation of ground water resources by rich farmers adversely affects the small and marginal farmers, whose wells may go dry in course of time. However, a close reading of the relevant portion of clause 7 of the Act gives a new insight. The act says;

“The right of every owner of land *to collect and dispose within his own limits of all water under the land which does not pass in a defined channel* and all water on its surface which does not pass in a defined channel.”

It has been proved that ground water is a dynamic resource and flows in a definite direction. Pumping of ground water from any abstraction structure affects the flow pattern. Hence, the right of a land owner to collect or dispose water within his land can be argued to be limited to the quantum which will not adversely affect the flow pattern. This matter should be taken up at appropriate government level to clarify the legal position of ground water ownership.

Pricing and Sectoral Allocation of Ground Water

It is increasingly being recognized that while maintaining its social characteristics, water is to be considered an economic good. Irrigation and water supply projects have traditionally been viewed as instruments of development, social benefits and as net addition to agricultural output and the national economy. In the domestic sector too, water is treated as a basic human need, to be made available to everybody irrespective of economic status. Thus, pricing of water in actual terms has not been implemented so far. However, undue advantage of this social stance on water pricing is being taken by the affluent class of the society. Affluent farmers, water intensive industries, water based amusement centres, posh urban residential colonies are enjoying the benefits of highly subsidized price of water even though they can afford to pay the actual cost. Since water is available without any financial liabilities worth bothering, these water guzzling instruments are indiscriminately extracting ground water without paying any heed to environmental or social considerations. Hence, there is a need to allocate water at a cost commensurate with demand among various users as the present pricing structure does not provide necessary incentives for its efficient use. Pricing of ground water can play a very important role in increasing water use efficiency.

The rate of ground water withdrawal is also intimately related to the power tariff. A major part of electricity delivered to the agriculture sector is used to pump ground water for irrigation. Presently, power is supplied to rural areas at highly subsidized rates or at flat rates, rather than based on actual power consumption. The highly subsidized rate, combined with inefficient and unreliable power supplies encourages indiscriminate withdrawal of ground water and sale of water in informal water markets. Provision for unmetered power to the agricultural sector creates an accountability gap and generates opportunities for large unaccounted losses. Restoration of financial viability of the power sector through appropriate pricing as a first step will be essential for ensuring the long-term sustainability of ground water resources. The revision of power tariffs should of course be combined with improved quality and reliability of power supply. The Government of Gujarat, under its *Jyotigram Yojana,* has evolved an innovative approach for rural power supply. Separate feeders were provided for domestic power supply and irrigation use. Villages get 24 hour three- phase power supply for domestic uses subject to metered tariff, whereas tube well owners get eight hours/day of power, but of full voltage and on a pre-announced schedule (Shah and Verma, 2007). The experience in Gujarat shows that redesigning of power supply mechanism can be effective in controlling the electricity consumption and thereby reducing ground water withdrawal.

Ground water is a dynamic resource occurring in regionally inter-connected systems. Any change in the pattern of development in one part of the system tends to affect the availability, quality and economics of supplies elsewhere in the system. The absence of a clear and well-defined ground water allocation policy for various sectors has the potential to foster unhealthy competition among users of this common pool resource. This may result in indiscriminate withdrawal of ground water in a bid to get maximum benefit before it is exhausted, and may widen the demand supply gap considerably. A well thought of water allocation policy is urgently required to address this problem and to ensure equitable distribution of available resources with built-in safeguards for its sustainability wherever necessary.

Regulation of Ground Water Development

Regulation of over-exploitation of ground water through legal means can be effective under extreme situations if implemented with caution. Ground water regulatory measures in India are implemented both at Central and State level. The central Ground Water Authority, constituted under Environment (Protection) Act of 1986 is playing a key role in regulation and control of ground water development in the country. Central Ground Water Authority initially notifies over-exploited areas in a phased manner for registration of ground water abstraction structures. 65 areas in various parts of the country have been notified for registration of ground water abstraction structures. Based on data thus generated, vulnerable areas are notified for the purpose of ground water regulation. So far, CGWA has notified 43 areas for regulation of ground water use. In these areas, construction of new ground water abstraction structures is regulated.

As water is a State subject, the management of ground water resources is a prerogative of the concerned State Government. In an effort to control and regulate the development of ground water, the Ministry of Water resources has prepared and circulated a Model Bill to all States and Union Territories in 1970 which was re-circulated in 1992, 1996 and 2005 for adoption. The main thrust of the bill is to ensure that all the States and Union Territories form their own State Ground Water Authorities for proper control and regulation of ground water resources. Some of the States like Andhra Pradesh, Bihar, Goa, Tamil Nadu, Himachal Pradesh, Kerala, and West Bengal and the Union Territories of Puducherry (Pondicherry), Chandigarh and Lakshadweep have already enacted ground water legislation.

As water is a basic need and thereby an important social issue, the regulatory mechanism needs to be transparent and people-friendly. Continuous monitoring of ground water regime is required in notified areas. Micro-level studies needs to be taken up in such areas on a regular basis to assess the impacts of the regulatory measures on the ground water regime. Real-time dissemination of information on the ground water situation in the affected areas is to be provided to the stakeholders. Involving local people in the administrative process as social volunteers may also help.

International experiences in ground water regulation and management are varied. United States ground water management practices are more in the form of financial incentives. In Spain and Mexico, water laws are formulated making ground water a national property. However, implementation of various clauses of ground water legislation could not be effectively achieved on a large scale in these countries (Planning Commission, 2007). National and international experiences indicate that enforcement of legislative measures for ground water regulation and management would be meaningful only when stakeholders are motivated through local self governing bodies and directly involved in the decision-making and enforcement process.

Water Saving Measures

Studies have shown that substantial quantity of water could be saved by the introduction of micro irrigation techniques in agriculture. Micro irrigation sprinklers and drip systems can be adopted for meeting the water requirement of crops on any irrigable soils except in very windy and hot climates. These water conservation techniques would provide uniform wetting and efficient water use. Although much of this can be achieved through private sector initiatives, it is important to ensure the availability of credit for purchasing equipments. In addition, mechanisms for encouraging adoption of these techniques by lower-income groups also need to be put in place.

Changes in cropping pattern aimed at higher return of investment may lead to increased exploitation of ground water, as the experiences in Punjab and Haryana have shown. Suitable scientific innovations may be necessary to solve this issue. Less water intensive crops having higher market value, scientific on-farm management, sharing of water and rotational operation of tube wells to minimize well interference and similar alternatives can provide viable solutions for balancing agro-economics with environmental equilibrium.

Broadening the limits of the quality of water used in agriculture can help manage the available water better in areas where scarcity of water is due to salinity of the available ground water resources. Cultivation of salt tolerant crops in arid/semi-arid lands, dual water supply system in urban settlements - fresh treated water for drinking water supply and brackish ground water for other domestic uses are some such examples. Recycling of water after proper treatment for secondary and tertiary uses is another alternative that could be popularized to meet requirements of water in face of the scarcity of resource in the cities.

Stakeholder Participation and Awareness

Unlike major and medium irrigation projects which are mostly State-run, most of the ground water development schemes result from private initiatives. The onus of management of this resource, therefore, lies with the people. Implementation of any large scale ground water development scheme is not likely to succeed, unless peoples' participation is ensured in planning, execution, and operation and maintenance of the scheme. However, due to lack of awareness, there is considerable lack of initiative at present from the stakeholders in addressing the management needs of the ground water sector. In order to involve the water users and the private sector in water management initiatives, it is necessary that comprehensive information pertaining to the ground water regime, both qualitative and quantitative, be made available to the stakeholders on a regular basis. Such an initiative is likely to motivate the users to take an active interest and involve themselves in the process of sustainable management of ground water resources. A shared understanding of the problems with the stakeholders can also generate the much needed financial resources and expertise to prove that ground water resources can be profitably managed. There is an urgent need to make a concerted effort on sharing of knowledge and information on ground water science with the common people through various platforms involving educational institutions, non-Governmental organizations, social activist groups, local self governing bodies etc. so that an integrated plan for management of our limited ground water resources can be implemented to ensure their long-term sustainability.

Conclusions

The increasing dependence on ground water as the major source of water supplies for agricultural, domestic and industrial sectors in India, coupled with the indiscriminate and unscientific exploitation of the limited available resources has necessitated a reorientation of the strategies of ground water management to ensure its long-term sustainability. The highly diversified hydrogeologic settings and variations in the availability of ground water resources as total and in terms of natural rainfall recharge from one part of the country to another call for a holistic approach for development of suitable management strategies. The emphasis on management does not imply that ground water resources in India are fully developed. There is a vast area in the Indo Gangetic alluvial tract where the ground water development is at low key and there is sufficient scope for future development. Similarly, urgent action is required to augment the ground water in the stress areas. However, focus on development activities must now be balanced by management mechanisms to achieve a sustainable utilization of ground water resources. Effective management of available ground water resources requires an integrated approach, combining both supply side and demand side measures. There is need for coordinated efforts from various Central and State Government agencies, non-Governmental and social service organizations, academic institutions and the stakeholders for planning and implementing management strategies suitable for the prevailing situations to ensure the long-term sustainability of ground water resources in the country.

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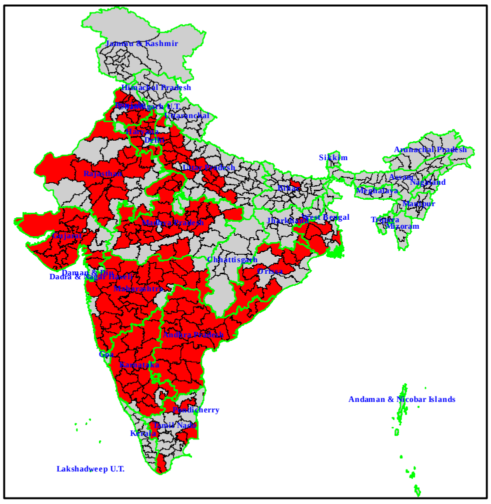
DETERIORATING GROUND WATER QUALITY AND ITS IMPLICATIONS ON RURAL WATER SUPPLY IN INDIA

A. Bhattacharyya*

In India, rural drinking water supply systems are predominantly dependent on ground water. Technology development in drilling and pumping methods have resulted in massive exploitation of ground water mainly for irrigation, which is about 85% of the total withdrawal and for industry and domestic purposes, it is approximately 15%. Exploration of ground water to meet the increasing demand of exploding population is causing imbalance between over-withdrawal of ground water and the deficient recharge, which has resulted in rapid lowering of water table. In several locations in the country, there is abnormal permanent fall in water table to the tune of 2 to 3 meters every year causing drying up of large numbers of drinking water sources. This resulted in slipping back of large numbers of habitations from fully covered to uncovered habitations. As per the 2003 National Survey conducted by Department of Drinking Water Supply, about 3.5 lakh habitations have slipped back, of which it is ascertained that more than 60% is due to ground water depletion and deteriorating ground water quality.

As per CGWB report, the situation is grave in 7% of the total area of the country where the stage of ground water development is more than 85%. It has reached critical stage in 11% of the area where the stage of ground water development is *65% - 85%.* Over-withdrawal along the coastal areas has resulted in saline water intrusion and contamination of the potable ground water aquifers. The indiscriminate over-drawl has changed the hydro-geochemical environments of the aquifers and in general enhanced toxic and undesirable chemical constituents of water beyond the permissible limit viz. fluoride, arsenic, total dissolved solids, iron, nitrate etc. with direct health implications leading to manifestations of various diseases. The fluoride contamination affects people in more than 29030 habitations in 17 states and excess arsenic in 7067 habitations in 5 States and is extensive in 5408 habitations (8 districts) of West Bengal followed by Assam and Bihar. Manifestations of diseases due to excess chemical contamination especially fluoride and arsenic has caused innumerable suffering and miseries to the community. The lack of complete and reliable data, however, makes it difficult to appreciate the magnitude and impact of the problem.

Depleting Ground Water



- Heavy extraction of Ground Water, especially for irrigation – Ground Water levels in many districts have fallen by more than 4 metres (@ > 20 cm/year) during 1981-2000.
- 15% of the blocks fall under dark/grey/over-exploited area
- Source: CGWB

*Joint Secretary, Ministry of Rural Development, Department of Drinking Water Supply, Government of India

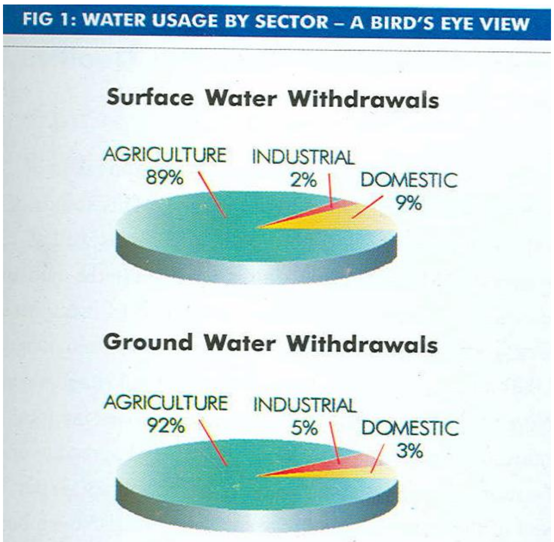
The rate at which the upper aquifers are getting depleted, side by side with deteriorating water quality makes the investments already made a huge waste because it would require further large investments for providing alternate safe distance (both vertical and horizontal) drinking water sources to rural population over 720 million residing in 3.29 million square kilometers. India has witnessed phenomenal development of water resources and self-sufficiency in food grain, rapid expansion in the urban, energy and industrial sectors, and drinking water infrastructure for both urban and rural population. However, this achievement has been at the cost of rapid and extensive ground water depletion, water logging in some areas, water quality degradation and pollution affecting fresh water resources. As a result, India's finite and fragile water resources are under stress, while sectoral demands are increasing. Per capita water availability has been falling drastically as indicated in the table 1 below:

Table 1: Population and Water Availability Trends in India

Year	Population in million	Water availability in m^3/yr/capita
1947	400	5000
2000	1000	2000
2025	1390	1500
2050	1600	1000

Source: India Water Resources Management Sector Review , World Bank1998

Such aggregate indicators, which do not reflect local conditions or seasonal availability, only partly illustrate the development of water constraints in India. While resources may be plentiful in such areas as Eastern and Northeastern India, in other areas rainfall is unreliable and or acutely short.



Source: Earth Trends 2001, World Resources Institute

Figure 1 clearly indicates that drinking water is a very small consumer of both the surface and ground water and over exploitation of ground water is primarily due to its extensive and indiscriminate use for agriculture . Comprehensive management and conjunctive use of both surface and ground water, incorporating both quality and quantity aspects of water is largely lacking.

Water being the basic requirement for any development programme, its management should be taken up seriously by the planners and given utmost priority with a bottom up approach involving community from the beginning of the programme planning and implementation. The harnessing and utilization of surface water resources being mostly in public sector, its exploitation is more or less under control but the exploitation of ground water being mostly in private sector, ground water legislation for its equitable and judicious use is must. If the implementation of the legislation is going to be delayed, there is need for declaring the site of domestic water supply well as notified area and prevention of any new ground water exploitation structure within 500 meters radius from such a well. In case of rainfall below normal, no ground water extraction should be allowed for any purpose other than for domestic use from the notified area. In this connection the notification issued and implemented by the state of Maharashtra, mainly for protecting the sustainability of the drinking water sources may be adopted by other states.

Government subsidies provided to the agriculture sector only serves to exacerbate the situation. Highly subsidized irrigation electricity tariffs, and favorable investment terms offered for irrigation well construction has led to an indiscriminate and disproportionate level of ground water abstraction, resulting on further degradation of quantity and quality of ground water. As a consequence, in spite of more than Rs 65,000 Crore investment already made by the Central and State Governments in rural water supply sector development, the reliability of water supply and level of consumer satisfaction are still below the desired level.

To improve the management of water resources, greater knowledge about their quantity and quality is needed. Regular and systematic collection of hydro-meteorological, hydrological and hydro-geological data needs to be promoted and supplemented by a system for processing quantitative and qualitative information for various types of water bodies. In order to project future water needs, it is desirable to have data on consumption, quality, type of user and also the information necessary to estimate the effect of the application of different policy instruments (Tariffs taxes, etc.) influencing the various areas of demand. The demand for water for different purposes should be estimated at different periods of time in conformity with national development goals to provide the basis and the perspective for the planned development of available water resources.

The National mechanism for the management of water resources should apply the best measure to improve the existing system and the best available techniques for planning and design of conservation and distribution systems in the most efficient way and should equally attend to proper maintenance control at the national, regional and farm level to increase efficiency. The rights of individual exploitation of ground water in an aquifer need to be restricted both for economic reasons and for preventing inequitable distribution. The rights on ground water should be that of use and not of ownership. Regulation, monitoring and enforcement to prevent over-exploitation entirely through the bureaucracy will be impossible. Some form of collective rights with the responsibility for regulation to be devolved on local communities seems essential.

To safeguard the sustainable supply of safe drinking water, concerted action is needed on all the fronts, including agriculture, urban and spatial planning, population planning, power generation, and industrial development. To prevent further depletion and degradation of freshwater resources, a more holistic approach is being promoted, which is known as Integrated Water Resource Management (IWRM). The objective of Integrated Water Resource Development and Management is to ensure optimal and sustainable use of water resources for economic and social development, while protecting and improving the ecological value of the environment. IWRM is necessary to combat increasing water scarcity and pollution. Methods include water pricing, allocation, conservation and reuse, rainwater harvesting and wastewater management. All water developmental projects need to be integrated at the micro and macro levels. An appropriate mix of legislation, pricing policy and enforcement measures is essential to optimize water conservation and protection. Furthermore, it has become clear that the provision of safe and sufficient water supply and sanitation facilities has to be placed within the wider context of 'Integrated Water Resources Management'.

The water supply and sanitation sector now faces two great challenges in developing countries. The first challenge is the implementation of the old agenda of providing household service. The second challenge is the implementation of the new agenda of environmentally sustainable development that includes each of the issues mentioned above, as they are all vitally important and necessary for achieving sustainable development.

I would like to draw the attention of all concerned to look into the alternatives of surface water based water supply schemes which is time consuming in implementation, capital cost intensive and not easily operated and maintained by the PRIs and community organizations. Awareness amongst people regarding the scarce nature of water resources and need for its quality protection should be developed. People's involvement and part ownership is essential for smooth functioning of any water supply scheme. Traditional water harvesting structures should be advocated both at the individual household level as well as community managed system, especially in remote and difficult terrains where implementation of drinking water supply system is not only a costly proposition but also a difficult task involving operation, maintenance and sustainability.

Proper and effective watershed management, rainwater harvesting as well as traditional water supply systems can also be an alternate source of safe water in arsenic and fluoride endemic areas, which will be more sustainable in the long run. Cost-effective and user-friendly technologies, which are available, should also be encouraged to solve this quality problem. At this juncture, it is appropriate to look back at the technology and scientific input in the development sector in the past.

Large numbers of water treatment plants viz. de-fluoridation plants, iron removal plants, desalination plants etc. installed in various states to tackle specific quality measures in drinking water sources through the centralized 'Sub-Mission" programme under the Water Mission have not met with much success. Technologies developed and tested to remove fluoride, iron etc, have shown satisfactory results in the laboratory environment. The complexity, high cost and inconvenience of these technologies, compounded by lack of trained and specialized manpower in rural areas however, have constrained their implementation and sustainability in the field conditions.

To be "appropriate", a technology must be socially acceptable, affordable by the community, sustainable and manageable in the particular geo-hydrological and rural environment. The dynamics of rural transformation at the grass roots level in India requires a proper understanding of the relationship between technology, society economy and trained human resource at the village and the household levels. The need for such an understanding acquires added importance in the context of growing emphasis on micro level planning under the Panchayati Raj Act. Sustainability is conceived as a continuous flow of benefits to rural people with or without the active involvement of organizations that had stimulated those benefits in the first place. One of the prime reasons sited in different reports as the cause for such dismal performance of the system installed is the lack of participation of the beneficiaries of the community in decision making, including choice of technology.

Another important aspect is water quality. Improvements in existing strategies and the innovation of new techniques resting on a strong science and technology base will be needed to eliminate the pollution of surface and ground water resources, to improve water quality and to step up the recycling and re-use of water. Science and technology and training also have important roles to play in water resources development and management in general.

ROLE OF WATER QUALITY ASSESSMENT AUTHORITY (WQAA) IN ARRESTING WATER QUALITY DEGRADATION IN INDIA

Narender Kumar*, S.K. Srivastava** & M. C. Bhatnagar***

Background

Water is a prime natural resource and is a basic need for all living organisms, for propagation and economic upliftment. Development and management of water resources need to be governed utilizing collective wisdom for the growth of all. Optimum development and efficient utilization of water resources therefore assumes great significance.

Water Resources in our country are under serious threat from contamination due to discharge of untreated/partially treated municipal sewage and industrial trade effluents into rivers and lakes. Disposal of municipal garbage and hazardous solid wastes in low-lying areas also poses a threat as they reach the ground water table and contaminate the aquifer. Problem of pollution of national water resources has become a matter of serious concern in the country. In recent years the rivers are being used indiscriminately for disposal of municipal, industrial and agricultural wastes thereby polluting the river water as well as ground water beyond the permissible limits. Due to this, the rivers and ground water are gradually becoming unfit even for irrigation purposes at some places. Thus, it has become very essential to evaluate the environmental impacts on surface and ground water resources to minimize the progressive deterioration in the quality of water. Therefore, a detailed study of water quality in all the vulnerable reaches of rivers and ground water aquifers is imperative for better management and utility of water for different uses. It is therefore necessary to create a credible database on river and ground water quality and monitor the same at certain intervals of time which would help the decision makers in taking timely remedial measures.

Main Causes of Water Quality Degradation

Pollution due to:

1. Rapid Urbanization
2. Fertilizers and Pesticides Applied
3. Untreated Industrial Wastewater / Effluents
4. Diffuse Water-Pollution
5. Waste waters and Pollutants from Unsewered Towns
6. Sewage, Sullage and Pollutants from Urban Areas with Inadequate or Faulty Sewerage Treatment System
7. Pollutants in Leakages and those Escaping Due to Accidents during Transportation, Storage or Handling
8. Effluents, Leachates and Wash-over from Cattle-farms and Animal Husbandry
9. Drainage from Wetlands and Pollutants from Aqua-culture
10. Deposition of Air Pollutants

*Commissioner (Brahmaputra & Barak), B&B Wing, of Ministry of Water Resources, Govt. of India.
**Senior Joint Commissioner (Brahmaputra & Barak), B&B Wing, of Ministry of Water Resources, Govt. of India.
***Research Assistant, B&B Wing, of Ministry of Water Resources, Govt. of India.

In many parts of our country, water is likely to become a scarce resource in the coming decades. During the last five decades, India has witnessed a spectacular industrial development, rapid urbanization and increasing population. Because of this, the range of requirement for water has increased manifold resulting in water quality problems. Domestic and industrial wastewater is the major source of water pollution in our country. About 26,000 million litre of domestic water is generated every day, out of which only about 7,000 million litre is treated. Similarly, a large number of small-scale industries are not able to provide treatment to the wastewater generated from them. Ground water, which caters to about 85% of the domestic water requirement and about 50% irrigation needs in the country is also under severe threat of contamination from geogenic contaminants such as arsenic and fluoride and nitrate anthropogenic contaminants like causing concern for domestic, agricultural and industrial uses.

Presently, the Maintenance of the “wholesomeness” of the National water bodies is the subject matter of the Ministry of Environment and Forests under the Water Act. 1974 and Environment (Protection) Act (EPA) ,1986 as per allocation of business rules. Water Quality in the country is being monitored by several different agencies i.e. (i) The Central Water Commission (CWC), (ii) State Government agencies, i.e. State Ground Water Agencies, and State Pollution Control Boards, (iii) The Central Ground Water Board, (iv) The Central Pollution Control Board(CPCB), and (v) The National River Conservation Directorate (NRCD). The Central Water Commission and the State Governments are mainly concerned with the requirements of water for irrigation and drinking purposes, in terms of both quantity and quality. The Central Ground Water Board (CGWB) and the respective State Ground Water Agencies develop ground water resources with similar objectives. The Central Pollution Control Board and its state counterparts are mainly concerned with the monitoring of water quality deterioration, and are responsible for prevention and control of pollution under the Water Act, 1974, and the Environment (Protection) Act, 1986. The National River Conservation Directorate (NRCD), under Ministry of Environment & Forests also monitors water quality to evaluate the implementation of pollution abatement schemes for river conservation.

The multiplicity of agencies involved in water quality management in the country as stated above has thus led to lack of uniformity in monitoring parameters, frequency of monitoring, locational norms for sampling stations, standardization of analytical and sampling protocols, calibration of instruments, training of technical staff, and setting up credible databases. In the absence of credible databases, formulation of policies and schemes to address issues of water quality becomes difficult.

Against this background, under Hydrology Project in which water quality monitoring and upgradation/establishment of water quality stations and laboratories was an important component, a number of workshops including two national level water quality-monitoring workshops (for surface water and ground water) were held during the year 2000. The major observations and recommendations were that the coordination among various agencies in the field of water quality monitoring were required to be established on long term basis and proposals for formation of State Level Review Committees and Coordination Committee at the National Level was worked out. After detailed discussion with the HP Consultants, proposals for composition of State Level and Central Level Coordination Committee along with their terms of reference were drawn up and Water Quality Assessment Authority (WQAA) at Central Level was constituted by MOEF under the Environment (Protection) Act, 1986.

Constitution of Water Quality Assessment Authority (WQAA)

Ministry of Environment and Forests (MoEF) issued an *Extraordinary notification* in the "The Gazette of India", dated 22nd June, 2001 constituting the "Water Quality Assessment Authority (WQAA) vide MoEF S.O. 583(E) dated 29th May, 2001 (read with amendment as notified in MoEF S.O. 635 (E) dated 26.5.2004, S.O. 728 (E) dated 25.5.2005 and S.O. 751 (E) dated 26.4.2007) for a period of three years, subsequently extended up to 31.03.2012, with the powers and functions enumerated therein to improve the quality of National Water Resources.

The Authority under its function is to direct the agencies on issues listed to standardize Water Quality monitoring methods, ensure proper treatment of wastewater to restore the Water Quality of Surface and Ground Water, take up R&D activity related to Water Quality Management and for promoting recycling and reuse of treated wastewaters. The 12-member Authority is headed by the Secretary, Ministry of Environment & Forests as the Chairman and the Commissioner (Water Management, presently B&B), MOWR as the Member Secretary with the following constitution:

1.	Secretary, Ministry of Environment and Forests	CHAIRMAN
2.	Additional Secretary and Project Director, National River Conservation Directorate, Ministry of Environment and forests	MEMBER
3.	Chairman, Central Water Commission	MEMBER
4.	Additional Secretary, Ministry of Water Resources	MEMBER
5.	Advisor National River Conservation Directorate Ministry of Environment and Forests	MEMBER
6.	Joint Secretary, Ministry of Agriculture and Cooperation.	MEMBER
7.	Joint Secretary, Ministry of Urban Affairs and Poverty Alleviation (Presently Ministry of Urban Development)	MEMBER
8.	Chairman, Central Ground Water Authority	MEMBER
9.	Chairman, Central Pollution Control Board	MEMBER
10.	Director, Indian Agricultural Research Institute New Delhi	MEMBER
11.	Director, National Environmental Engineering Research Institute, Nagpur.	MEMBER
12.	Commissioner (Water Management, presently B&B), Ministry of Water Resources	MEMBER SECRETARY

The Ministry of Water Resources is accordingly giving full support to the constituted Water Quality Assessment Authority (WQAA) in carrying out and coordinating its functions.

Powers and Functions of WQAA

The function of WQAA is to exercise powers under section 5 of the Environment (Protection) Act, 1986 for issuing directions and for taking measures with respect to matters referred to clause (ix), (xi), (xii) and (xiii) of sub-section 2 of section of the Environment (Protection) Act ,1986 in the following ways :

- to direct the agencies (government/local-bodies/non-governmental) to standardize method(s) for water quality monitoring and to ensure quality of data generation for utilization thereof,
- to take measures so as to ensure proper treatment of wastewater with a view to restoring the water quality of the river/water bodies to meet the designated-best-uses;
- to take up research and development activities in the area of water quality management;
- to promote recycling, re-use of treated sewage/trade effluent for irrigation in development of agriculture;
- to draw action plans for quality improvement in water bodies; monitor and review/assess implementation of the schemes launched/to be launched to that effect:
- to draw scheme(s) for imposition of restriction in surface water abstraction and discharge of treated sewage/trade effluent on land, rivers and other water bodies with a view to mitigate crisis of water quality;
- to maintain minimum discharge for sustenance of aquatic life forms in riverine system.
- to utilize self-assimilation capacities at critical river stretches to minimize cost of effluent treatment,
- to provide information to pollution control authorities to facilitate allocation of waste load;
- to review the status of quality of national water resources (both surface water & ground water except that due to geogenic aspect) and identity "Hot Spots" for taking necessary actions for improvement in water quality;
- to interact with the authorities/committees constituted or to be constituted under the provisions of the said Act for matters relating to management of water resources;
- to constitute/setup State-level Water Quality Review Committees (WQRC) to coordinate the work to be assigned to such committees; and
- to deal with any environmental issue concerning surface and ground water quality (except due to geogenic aspect) which may be referred to it by the Central Government or the State Government relating to the respective areas, for maintenance and /or restoration of quality to sustain designated-best-uses.

Activities

Under WQAA, the main activities include holding meetings of WQAA & WQMC to take major decisions in respect of Water Quality issues, organizing National and Regional level workshops for interaction amongst the states and central agencies with a view to provide guidance on state specific issues, arranging studies and training etc. Some of the main activities are as follows:

- The Water Quality Assessment Authority held its first meeting on 26.9.2001. In this meeting, the objective and importance for constituting authority was discussed. In this meeting, various important issues to find the ways and means in solving the crisis of potable water throughout the country by giving examples of region-specific problems, the need for bringing uniformity in the water quality monitoring system and co-ordination amongst the various central and state agencies were discussed. Also, it was decided to constitute a small committee namely Expert Group; to review present status and suggest measures for bringing in uniformity in the Water Quality

Monitoring procedures so that the data generated by each agency is compatible and of known quality. The composition and scope of work of the Water Quality Review Committees (WQRC) in States was approved in the meetings. It was decided to write to the respective Chief Secretaries to constitute State Level Water Quality Review Committees. The matter of creation of co-ordination cell in MOWR to assist the WQAA and its staff requirement were discussed and decided. Its aims and objectives were also discussed.

- In its 2nd meeting held on 14.5.2003, various issues mentioned in the Expert Group Report were discussed in detail and finally the Authority generally accepted and approved the report regarding the Monitoring Protocol. It was decided that the National River Conservation Directorate, MOEF may consider bringing out a Gazette Notification of the Monitoring Protocol for adoption by all the water quality monitoring agencies. Apart from the above, the following Committees were constituted in this meeting:

    1. Water Quality Monitoring Committee – To assist the WQAA in performing its functions.
    2. Task Force – To recommend measures for optimum Water Quality observation network and to coordinate data collection and dissemination system to assist the WQAA.
    3. Working Group – To advise the WQAA on the minimum flows in the rivers to conserve the eco system.

    - In the 3rd meeting of WQAA held on 9.12.2004, the draft Notification for Monitoring Protocol was prepared and circulated for comments.

    - In the 4th meeting of WQAA held on 19.7.2005, the recommendations / conclusion of the Expert Group on Water Quality Monitoring System were reviewed. The Gazette Notification for Uniform Monitoring Protocol was made on 17.6.2005 vide S.O. 2151 by MoEF after approval of Law Ministry. It was decided that from 11th Plan onwards, funding of Water Quality Projects through NRCD would be subject to approval of Water Quality Management Plans for polluted areas submitted by States.

(i) In the 5th meeting of WQAA held on 3.8.2006, the follow up action on the implementation of the Uniform Monitoring Protocol for Water Quality was reviewed. It was decided that:

    i. It is mandatory for laboratories doing water quality analysis to obtain EPA, NABL, ISO or equivalent certificates.
    ii. Manpower in laboratories can be either recruited by the concerned department or can be outsourced, and
    iii. Expenditure in this respect will be met by internal resources of the concerned organization.

The recommendations of the Working Group on Minimum flows were discussed in this meeting. It was decided that the Working Group may carry out further studies including the institutional and legal implications of the recommendation. The Working

Group was also suggested to take water quality aspects into consideration, particularly in most critical stretches of the rivers. In the meeting, CPCB informed that the Water Quality Data Bank at National Level is operational.

Other Activities

- WQAA gave oral evidence on 3rd December, 2003 before Joint Parliamentary Committee on Pesticide Residues and Safety Standard for Soft Drinks, Fruit Juice, and Other Beverages.

- A National Level Strategy Workshop for WQRCs was held in New Delhi on 20-21st July, 2005 to interact on related issues/matters and functioning of the committees to enable evolving more effective strategy for action.

- Regional workshops for Western, Northern, Southern and Eastern Region were also held at Pune, New Delhi, Hyderabad and Bhubaneswar respectively.

- Constitution of Central Referral Laboratories.

    - One referral laboratory for surface water has been set up by CWC at New Delhi while two referral laboratories for ground water have been set up by CGWB at Lucknow and Hyderabad.

Achievements of WQAA

The main achievements of the Authority so far are as follows:

- So far 5 meetings of WQAA have been held. It has constituted a Water Quality Monitoring Committee (WQMC) to assist it in performing its functions. WQAA has also constituted three Standing Groups to deal with specific functions as per their Terms of Reference. A Working Group has also been constituted by WQAA to study issues relating to minimum flows in riverine systems.

- On the basis of its Term of Reference (TOR), WQAA made a review of water quality related activities in the country for improvement in this regard. For this purpose, WQAA constituted an Expert Group on Water Quality Monitoring Systems with a view to unifying and streamlining the widely varying water Quality Monitoring Systems being followed at present by various central and state agencies. . The Expert Group submitted its report after reviewing the present status of surface water and ground water monitoring programme of the central and state agencies and the report has been accepted and approved by Competent Authority. Also a Task Force was constituted to recommend measures for optimum Water Quality Observation Network and coordinated data collection and dissemination system. On the basis of the recommendation of the Expert Group and Task Force, Ministry of Environment & Forest (MoEF) formulated the Uniform Protocol on Water Quality Monitoring and a Gazette Notification on Uniform Monitoring Protocol was published in the Gazette of India on 18th June, 2005. It was circulated to all the states and concerned central agencies for implementation.

- State Level Water Quality Review Committees have been constituted so far in 34 States/UTs, to coordinate works assigned to them in respect of Water Quality such as Water Quality Monitoring Network, identification of problem areas etc.

- The WQAA also decided that while approving projects meant for Water Quality abatement, holistic view about water quality management aspect needs to be adopted and considered for funding of scheme by agencies like National River Conservation Directorate (NRCD) MoEF, Ministry of Urban Development (MoUD), Ministry of Rural Development (MoRD) etc.
- Through the Authority, interaction among all the states and the concerned central agencies was organized and role of water quality review committees towards water quality management, identification of problem areas and hot spots, evaluation of existing system of monitoring network and implementation of awareness and graded training were emphasized.

- On the basic studies on conservation of eco system, the WQAA has carried out a study on minimum flow of rivers through a Working Group. The scope of this study has been further enhanced.

- The Authority is making review of Water Quality related matters on a continuous basis as per the objective set for it through Water Quality Monitoring Committee (WQMC) and its three Standing Groups.

Conclusion

In this way, the Water Quality Assessment Authority (WQAA) is an appropriate inter-ministerial Authority to deal with the water quality issues prevailing in different sectors of the country. Since the last 5 years, this Authority has been striving to contribute significantly to make the water quality conservation successful in the country. But it will have to tread a long way still in order to achieve the goal of arresting the Water Quality degradation in the country.

GROUND WATER QUALITY IN INDIA AND ITS MANAGEMENT

B. C. Mehta*

Introduction

Ground water is an essential and vital component of our life support system. The ground water resources are being utilized for drinking, irrigation and industrial purposes. There are exploitation pressure on ground water resources and growing concern of deterioration of ground water quality due to geogenic and anthropogenic activities such as unplanned disposal of industrial effluents ,sewage and sewerage. The over exploitation of ground water has resulted in the lowering of water level and deterioration in ground water quality.

The quality of water is judged by the presence of dissolved solids and micro organism. The chemistry of ground water has an unusual characteristic in terms of its ability to dissolve a greater range of substances than any other liquid by virtue of its occurrence in different environmental conditions controlled by specific pressure and temperature distinctly different from the conditions on land. Dissolved constituents in the water provide clues to its geologic history, its influence on the soil or rock masses through which its has passed, the presence of hidden ore deposits and its mode of origin within hydrologic cycle. Chemical processes in the ground water zone can influence the geological materials. In the study of landscape evolution, the assumption is commonly made that the physical processes of erosion, thermal expansion and contraction, frost action and slope movements are the demonical influences but on closer look it is often found that chemical processes in the ground water zone are the controlling influences.

The quality of ground water has undergone a change to an extent that the use of such water could be hazardous. Increase in overall salinity of the ground water and/or presence of high concentrations of fluoride, nitrate, iron, arsenic, total hardness and few toxic metal ions have been noticed in large areas in several states of India.

Hydrogeology

India is a vast country having an area of 329 million hectares, out of which about 3/4(239 million hectares) is hard rock and rest is alluvium (0.89 million hectares). It is bestowed with sizeable ground water resources mainly contributed by rainfall and seepage from unlined canals and tanks. It has diversified geological settings. The occurrence of different litho-units in the country reveals that a large part of the country is occupied or underlain at shallow depths by consolidated rocks, whereas porous formations occupy the rest. Both porous (un-consolidated and semi-consolidated) and fissured (consolidated) formations are, by and large, the important repositories of ground water. However, aquifers in these formations have different properties like storage, transmissivity, yield etc.

Factors Affecting the Ground Water Quality

As a result of chemical and biochemical interactions between ground water and the geological materials through which water flows and to a lesser extent because of contribution from the atmosphere and surface water bodies, ground water contains wide varieties of dissolved inorganic chemical constituents in various concentrations

*Scientist ‘D’, Central Ground Water Board.

The processes which explain the changes in the chemical characteristics of ground water with depth and distance along the flow paths include the following.

a) Dissolved Gases.

Gases like CO_2, CH_4, and H_2S often exist in ground water in significant concentrations because they are the products of biogeochemical processes that occur in the non aerated subsurface zone. These gases, when present, may render the ground water useless and may cause major problems.

b) Reactions of Carbonic acid

The CO_2 charged water which infiltrates through the soil zone, commonly encounters minerals that can be dissolved under the influence of CO_2 or H_2CO_3 (or H^+ + HCO_3^-) resulting in the dissolution of calcite or dolomite as the pH and bicarbonate contents of water rise.

c) Oxidation and Reduction Processes

Rain water at the moment of infiltration is strongly oxidising due to equilibrium with atmospheric oxygen (Eh around 800 mv). The tendency of ground water is towards oxygen depletion because the oxygen present is consumed in hydrochemical and biochemical processes and is not replenished. Thus their reactions in the ground water environment involve the transfer of electrons. The complex interactions between the oxidising recharge water and the reducing aquifer material are responsible for the oxidation – reduction processes. When all the dissolved oxygen in ground water is consumed, oxidation of organic matter can still occur but the oxidising agents (to be reduced) are NO_3^-, MnO_2, Fe (OH), SO_4^{-2}. Due to consumption of organic matter, the ground water environment becomes more and more reducing.

d) Ion Exchange Processes

Geological materials are mostly porous surfaces because the geochemical products of rocks are often inorganic, amorphous colloids in metastable state. The ion exchange processes are almost exclusively limited to colloidal particles because these particles have high electrical charge.

e) Silicate Mineral Reactions

These are the key processes in the chemical evolution of ground water. Crystalline rocks of igneous or metamorphic origin generally have appreciable amounts of quartz and alumina silicate minerals. These minerals are thermodynamically unstable and tend to dissolve comes when in contact with water. The dissolution process cause the water to acquire dissolved ions and rocks to become altered mineralogically.

h) Presence of Micro organisms

Micro-organisms are present everywhere in the soil. Bacteria play a very important role in geochemical processes. Bacteria that can thrive only in the presence of dissolved oxygen are known as aerobic bacteria. Anaerobic bacteria require an absence of dissolved oxygen, while facultative bacteria can thrive with or without oxygen. These micro-organisms catalyse nearly all the redox reactions that occur in the ground water. Iron and Sulphate reducing bacteria are very common in ground water.

i) Mixing with connate water

Connate water, when highly saline may also affect the chemical composition of fresher natural waters indirectly by osmosis. When two aqueous phases having different salt content are separated by a semi permeable membrane (e.g. Clay), water molecules from the more diluted solution will tend to diffuse into the more concentrated solution.

j) Saline Water Intrusion

In case where aquifers are hydraulically connected to the sea or to saline water bodies, over pumping may disturb the normal hydraulic gradient and discharge of ground water into the sea may be reversed, resulting in the intrusion of saline water into the aquifers.

In hydrological cycle, a large number of factors are to be considered including the ground water contaminant. It is not possible to consider all of them at a time. We will be considering some of the more important contaminants of ground water, mainly geogenic, which have direct bearing on human health and environment.

Ground Water Quality in India

In general, ground water in shallow aquifers is suitable for use for different purposes and is mainly of Calcium bicarbonate and mixed type. However, other types of water are also available including Sodium-Chloride water. The quality in deeper aquifers varies from place to place and exploration work is still going on to find out the disposition of different aquifers with suitable quality and quantity. Only in some cases, ground water has been found not suitable for use due to various contamination mainly because of geogenic reasons. Some of the ground water quality problems in India are:

Inland Salinity

Inland salinity in ground water is prevalent mainly in the arid and semi arid regions of Rajasthan, Haryana, Punjab and Gujarat and to a lesser extent in Uttar Pradesh, Delhi, Madhya Pradesh Maharashtra, Karnataka and Tamil Nadu. About 1.93 lakh sq.km area has been estimated to be affected by saline water of Electrical Conductivity in excess of 4000 μ S/cm (Table-1). There are several places in Rajasthan and southern Haryana where EC values of ground water is greater than 10000 μ S/cm making water non-potable. In some areas of Rajasthan and Gujarat, ground water salinity is so high that the well water is directly used for salt manufacturing by solar evaporation.

The salt contents in ground water depend upon the source and on the aquifer through which it moves. Factors which apparently influence relative ground water salinity are as follows-

- Imbalance between annual evaporation, precipitation and runoff
- Rate of weathering
- Transportation of salts into the region by stream, wind and rain.
- Permeability and hydraulic gradient of the aquifer and confining bed.
- The rate of ground water circulation and rate of salt accumulation in the aquifer body from infiltrating water.
- Inherent saline ground water.

Table –1 Area Affected by Inland Salinity in Ground Water (EC > 4000 μS/cm)

S. No.	State	Total Area of the State (Sq.Km)	Area underlain by Saline Ground Water (Sq.Km)	% Area
1.	Haryana	44212	11438	25.87
2.	Punjab	50353	3058	06.07
3.	Delhi	1485	140	09.43
4.	Rajasthan	342239	141036	04.12
5.	Gujarat	196024	24300	12.40
6.	Uttar Pradesh	294411	1362	00.46
7.	Karnataka	191791	8804	04.59
8.	Tamil Nadu	130058	3300	02.54
	Total	**1250573**	**193438**	**15.47**

Ground water is dynamic in nature. It is generally remains in equilibrium with Ca ion in areas of discharge. When ground water approaches the soil surface, the carbon dioxide pressure drops due to the escape of the gas. This causes precipitation of calcite and sometime, even magnesium calcites. If evaporation process is strong, even gypsum may get precipitated. Consequently, with an increase in mineralisation, the water in arid and semi arid zones changes from alkaline Bicarbonate–Sulphate type to Sodium-Chloride type with the formation of kankar in the intervening stage.

Inland salinity is also caused due to practice of surface water irrigation without consideration of ground water status. The gradual rise of ground water levels with time has resulted in water logging and heavy evaporation in semi arid regions lead to salinity problem in command areas. As per recent assessment about 2.46 m ha of the area under surface water irrigation projects is water logged or threatened by water logging.

For scientific development of ground water resources in the inland salinity areas, the following measures are required to be taken:

- Assessment of saline ground water resources based on data of exploratory drilling to determine the aquifer geometry and hydraulic parameters.
- Use of anticorrosive materials in production tube wells in these areas.
- Conjunctive use of surface and ground water in irrigation projects.
- Irrigation Management and cropping pattern.
- Horticulture and afforestation
- Water conservation and artificial recharge of ground water.
- Regulation of ground water development in areas with fresh water floats on brackish water.

Coastal Salinity

Coastal areas represent zones where land and sea meet and comprises variety of complex environments including deltas, estuaries, bays, marshes, dunes and beaches. Coastal aquifers have boundaries in contact with seawater and are always under dynamic equilibrium with it. Withdrawal of fresh ground water from these aquifers may result in inequilibrium resulting in intrusion of saline water in coastal aquifers.

The Indian subcontinent has a dynamic coast line of about 7500 km length. It stretches from Rann of Kutch in Gujarat to Konkan and Malabar coast to Kanyakumari in the south to northwards along the Coromandal coast to Sunderbans in West Bengal .The western coast is charactrised by wide continental shelf and is marked by backwaters and mud flats while the eastern coast has a narrow continental shelf and is characterized by deltaic and estuarine land forms. Ground water in coastal areas occurs under unconfined to confined conditions in a wide range of unconsolidated and consolidated formations.

Normally, saline water bodies owe their origin to entrapped sea water (connate water), sea water ingress, leachates from navigation canals constructed along the coast, leachates from salt pans etc. In general, the following situations are encountered in coastal areas

i. Saline water overlying fresh water aquifer
ii. Fresh water overlying saline water
iii. Alternating sequence of fresh water and saline water aquifers

In India, salinity problems have been observed in a number of places in coastal areas of the country. Problem of salinity ingress has been noticed in Minjur area of Tamil Nadu and Mangrol – Chorwad- Porbander belt along the Saurashtra coast. In Orissa in an 8-10 km. wide belt of Subarnrekha, Salandi, Brahamani outfall regions in the proximity of the coast, the upper aquifers contain saline horizons decreasing landwards. Salinity ingress is also reported in Pondicherry region, east of Neyveli Lignite Mines.

To effectively counter the problems of salinity ingress and other related problems caused by unplanned development of ground water in coastal areas the following strategies are called for:

1. Intensify Hydrogeological and hydro geophysical studies to delineate fresh – saline water interface.
2. Proper planning and designing of well fields for extraction of ground water.
3. Periodical monitoring of both water level and water quality for time series analysis of the data.
4. Study of hydrochemical parameters and stable isotopes to identify the sea water intrusion due to over exploitation.
5. Precise estimation of exploitable ground water resources and ground water outflow from coastal aquifers.
6. Mathematical modelling of ground water flow.
7. Regulation of utilization of ground water development through suitable legislation.
8. Miscellaneous administrative measures including restriction of further ground water development in ‘critical’ and over-exploited blocks.
9. Conjunctive use of surface water and ground water.
10. Use of brackish water for salt tolerant crops and prawn cultivation.

Fluoride

Fluorine is the lightest member of the halogen group of elements. Fluorite (CaF_2) is a common fluoride mineral. This mineral has a rather low solubility and occurs in both igneous and sedimentary rocks. Apatite (Ca_5 (Cl, F, OH) ($PO_4)_3$,) commonly contains fluoride. Most fluorides are sparingly soluble and are present in natural water in small amounts.

High concentration of fluoride in ground water beyond the permissible limit of 1.5 mg/L is a major health problem in India. Nearly 90% of rural population of the country uses ground water for drinking and domestic purposes. With 199 districts of 19 states of India identified with problem of excess Fluoride in ground water (Table-2), a huge rural population is threatened with serious health hazards of Fluorosis

Table 2. Fluoride in Ground Water of India

Sl. No.	State	No. of District Affected	Districts
1.	Andhra Pradesh	16	All districts except Adilabad, Nizamabad, West Godavari, East Godavari, Vishakhapatnam, Srikakulam, Vizianagaram
2	Assam	2	Karbi Anglong,Nagaon
3.	Bihar	5	Daltonganj,Gaya,Rohotas,Gopalganj,Paschim Champaran
4	Chhatisgarh	2	Durg, Dhantewalan
5	Delhi	7	Central,South,West,East,South west,North West,North East zones
6	Gujarat	18	All districts except Dang
7.	Haryana	11	Rewari,Faridabad,Karnal,Sonipat,Jind,Gurgaon, Mohindergarh, Rohtak, Kurukshetra, Kaithal, Bhiwani
8	Jammu & Kashmir	1	Doda
9	Jharkhand	4	Gridhi, Palamau,Pakur,Sahabganj
10	Karnataka	14	Dharwad,Gadag,Bellary,Belgaum,Raichur, Bijapr,Gulbarga,Chikmaglur,Mandya, Bangalore (rural), Mysore, Manglore, Kolar, Shimoga
11	Kerala	2	Palghat, Allepy
12	Maharashtra	8	Chandrapur, Bhandara, Nagpur, Jalgaon, Buldhana, Amravati, Akola, Yavatmal
13	Madhya Pradesh	13	Shivpuri,Jhabua,Mandla,Dindori,Chhindwara,Dhar,Vidhisha,Sehore, Raisen, Mandsour, Neemuch, Ujjain, Seoni
14	Orissa	18	Phulbani, Koraput, Dhenkenal, Angur, Boudh, Nayagarh, Puri,Balasore, Bhadrak, Bolangir, Ganjam, Jagatpur, Jajpur, Kalahandi,Keonjhar, Kurda, Mayurbhanj, Rayagada
15	Punjab	9	Mansa,Faridkot,Bhatinda,Muktsar,Moga,Sangrur, Ferozpur, Ludhiana, Amritsar
16	Rajasthan	32	All districts
17	Tamil Nadu	8	Salem, Erode, Dharma Uri, Combater, Tiruchirapalli, Vellore, Madurai, Virudunagar
18	Uttar Pradesh	7	Unnao,Agra,Meerut,Mathura,Aligarh,Raibarali , Allahabad
19	West Bengal	7	Birbhum,Bardman,Bankura,Purulia,Malda, U.Dinajpur & D.Dinajpur

To combat the growing problem of fluorosis, it is of utmost importance to understand the distribution and occurrence of fluoride in ground water and work out strategies for its mitigation and management. Some of the options available for removal of fluoride from drinking water are –

i. Adsorption (Activated Alumina)
ii. Ion Exchange
iii. Nalgonda Technique
iv. Membrane (Reverse Osmosis)
v . Electro dialysis
vi. Alternate Fluoride free aquifer

Arsenic

Arsenic and its compounds are widely used in pigments, as insecticides and herbicides, as an alloy in metals and chemical warfare agents. Though synthetic organic compounds have now replaced arsenic in most of the uses, arsenic is still an element of interest in terms of environmental quality.

Arsenic is a metalloid. The common valencies of arsenic in unpolluted ground water of geogenic origin are +III & +V as hydrolysis species The dissociation constant of As(III) and As(V) acids are quite different

The fact that dominant dissolved species are either uncharged or negatively charged suggests that adsorption and ion exchange will cause little retardation as these species are transported along ground water flow path. Organic arsenic compounds such as methyl arsenic acid and dimethyl arsenic acid are not common in ground water.

The occurrence of Arsenic in ground water was first reported in 1980 in West Bengal in India. In West Bengal, 79 blocks in 8 districts have Arsenic beyond the permissible limit of 0.01 mg/L. About 16 million people are in risk zone. The most affected districts are on the eastern side of Bhagirathi river in the districts of Malda, Murshidabad, Nadia, North 24 Parganas and South 24 Parganas and western side of the districts of Howrah, Hugli and Bardhman. The occurrence of Arsenic in ground water is mainly in the intermediate aquifer in the depth range of 20-100m. The deeper aquifers are free from Arsenic contamination. Apart from West Bengal, Arsenic contamination in ground water has been found in the states of Bihar, Chhatisgarh and Uttar Pradesh .In case of Bihar initially only 2 districts were reported as Arsenic affected but recently Arsenic in ground water has been reported in all 12 districts. It has also been reported in Dhemaji district of Assam. The occurrence of Arsenic in the states of Bihar, West Bengal and Uttar Pradesh is in Alluvium formation but in the state of Chhatisgarh, it is in the volcanics exclusively confined to N-S trending Dongargarh-Kotri ancient rift zone. Table 3 shows the occurrence of Arsenic in ground water in some state of India.

The remedial options available for getting Arsenic free in ground water are

1. Development of ground water from Arsenic free aquifers
2. Piped water supply from surface water sources.
3. Dilution of ground water with surface water
4. Treatment of ground water for removal of arsenic using adsorption(Activated alumina /Granulated ferric hydrated oxide) or precipitation and coagulation technique.
5. Rain water harvesting

Table 3   Arsenic in Ground Water of Some States of India.

State	District	Block
Bihar	Bhojpur	Barhar,Shahpur, Koilwar, Ara, Bihiya and Udawant nagar
	Patna	Maner, Danapur, Bakhtiarpur and Barh
Chhatisgarh	Rajnandgaon	Choki (11 villages)
West Bengal	Malda	English Bazar,Manickchak,Kaliachak I ,II&III Ratuaand I and II
	Murshidabad	RaninagarI&II, Domkal,Nowda, Jalangi, Hariharpara, Suti I&II Bhagwangola I & II, Beldanga I&II, Berhampur, Raghunathganj I & II, Farakka, Lalgola and Satshahganj
	Nadia	Karimpur I&II,Tehatta I &II, Kaliganj, Nawadwip, Haringhata, Chakda, Santipur,Naksipara,Hanskhali, Krishnaganj, Chapra, Ranaghat I&II, Krishnanagar I & II.
	North 24 Parganas	Habra I & II,Barasat I & II, Rajarhat, Deganga, Beduria, Gaighata, Amdanga, Bagda ,Boangaon, Haroa, Hasnabad, Basirhat I & II,Swarupnagar,Barackpur I & II, Sandeshkhali II
	South 24 Parganas	Baraipur,Sonarpur,Bhangar I & II,Joynagar I,Bishnupur I & II,Mograhat II,Budge Budge II
	Bardhman	Purbasthali I & II,Katwa I & II and Kala II
	Haora	Uluberia II and Shampur II
	Hugli	Balagarh
Uttar Pradesh	Ballia	Bilhari,Baria,Muralichapra,Reoati,Bansdih,Dubhad and Maner
	Lakhimpur Kheri	Palia,Nighasan,Ramia,Dauralwa and Issanagar
	Balrampur	Tulsipur,Gainsari,Pachparwa and Utaranla
	Gonda	Katrabazar,Haldarman,Tarabganj and Nawalganj
	Siddharth Nagar	Itawa and Khumiaon

Iron

Iron in an essential element for both plant and animal metabolism. Both ferrous and ferric iron are wide spread minor component of most sediments. Soil development processes result in increase in iron content. The concentration of iron in natural water is controlled by both physico chemical and microbiological factors. In aqueous solution iron is subject to hydrolysis and iron hydroxides are formed during these reactions, especially the ferric form having very low solubility.

The reaction of iron in aqueous solution is affected by redox potential and pH of the solution. In most natural water, pH ranges from 5 to 9 and as such is not low enough to prevent hydrolysis under oxidising conditions. Practically all the iron is precipitated as hydroxides. This ferric hydroxide may exist in colloidal suspensions in the range of 5 to 8. Organic rich water particularly those with humic acid, can contain dissolved iron over a large range of redox conditions. Organic compounds present in water consume dissolved oxygen which lowers the pH of water because of production of CO_2 reducing both pH and Eh. An additional factor involved in the mobility in iron in ground water is the presence of bacteria. These bacteria are Gallionela, Leptothrix and Thiobacilhus. Decay of these bacteria produce unpleasant odour.

To understand the behaviour of different iron species in ground water application of chemical equilibrium is very useful and the actual solubility of iron under different condition can be calculated using Eh – pH diagram.

High concentration of Iron in ground water has been observed in more than 1.1 lakh habitations in the country. The highest value(49 mg/L) has been found in a hand pump at Bhubaneswar. Ground water contaminated by iron has been reported from Assam, West Bengal, Orissa, Chhattisgarh, and Karnataka. Localized pockets are observed in states of Bihar, UP, Punjab, Rajasthan, Maharashtra, Madhya Pradesh, Jharkhand, Tamil Nadu, Kerala and North Eastern States.

Nitrates

Aqueous geochemical behaviour of nitrogen is strongly influenced by vital importance of the element in plant and animal nutrition. The most common contaminant identified in ground water is dissolved nitrogen in the form of nitrate (NO_3).

Decomposition of organic matter present in soils, leaching of soluble synthetic and natural fertilizers and human / animal excreta are the potential source of nitrate in subsurface water. Since the nitrogen content of soil is generally quite low, farmers have to look for external sources of nitrogen by using ammonium nitrate, calcium nitrate, urea, diammonium hydrogen phosphate etc. Although the concentration of nitrate in ground water system from industrial wastes is minimal as compared to both point and non point sources such as agriculture, local impacts can be severe e.g. synthesis of ammonia produces potential nitrogenous waste.

Nitrate in ground water generally originates from nitrogen sources on the land surface in the soil zone or shallow subsoil zones where nitrogen rich wastes are buried. In some situations nitrate that enters the ground water system originates as nitrate in wastes or fertilizers applied on the land surface. These are direct nitrate sources. In other cases nitrate originates by conversion of organic nitrogen. Ammonification and nitrification are processes that normally occur above the water table generally in the soil zone, where organic matter and oxygen are abundant.

Though various nitrogen products are available in the nitrogen cycle, the content of nitrate in Ground Water is probably controlled by nitrification which is directly related to the capacity of soil microorganisms to convert ammonia to nitrate to provide growing plants with the assimilable form of nitrogen

Concentrations of nitrate in the range commonly reported for ground water are not limited by solubility constraints. It moves with ground water with no transformation and / or no retardation. Very shallow ground water in highly permeable sediment or fractured rocks commonly contains considerable dissolved oxygen and in these hydrological environment nitrate commonly migrates large distances from input areas.

Nitrate ions can be readily converted in vivo to nitrite, which oxidizes hemoglobin to methemoglobin, a pigment, which is incapable of acting as oxygen carrier in blood. It has been well documented that milk feeds prepared for infants in water containing over 45mg NO_3/L (10mg NO_3-N/L) has been responsible for infants' methemoglobinemia (blue baby disease) which resulted in many fatal cases in the period 1940-1965

Nitrate is a very common constituent in the ground water, especially in shallow aquifers. The source is mainly from man made activities. In India, high concentration of nitrate has been found in many districts, the highest value being 3080 mg/L found in Bikaner, Rajasthan. Table-4 shows some of the districts where nitrate has been found in excess of 45 mg/l in ground water.

Table: 4 Nitrate in Ground Water of India

State	District having NO_3 >45 mg/L in Ground Water	Maximum Conc. Of NO_3 mg/L
Andhra Pradesh	Khammam, Nalgonda, Nizamabad, Guntur, Karimnagar, Kurnool, Mehboobnagar, Nellore, Prakasam and Vijaywada	1490 (Prakasam)
Bihar	Palamau, Gaya, Patna, Nalanda, Nawada, Bhagalpur, Sahebganj, and Banka	440 (Gaya)
Delhi	Shahadra,IIT,& NCERT campus	1600 (Samboli)
Haryana	Ambala, Sonepat, Jind, Gurgaon, Faridabad, Hissar, Sirsa, Kurukshetra, Karnal, Mahendragarh and Rhotak	1310 (Sirsa)
Himachal Pradesh	Una	176 (Una)
Karnataka	Banglore, Belgaum, Bellary, Bijapur, Chitradurga, Dharwar, Gulberga, Hassan,Kolar,Raichur,Shimoga	900Mandya)
Kerala	Idduki, Kottayam, Malapuram, Palaghat,	200(Palghat)
Madhya Pradesh	Bhind, Chindwara, Dewas, Dhar, Gwalior, Indore, Khandwa, Mandsaur,Morena,Sehore	2100(Sehore)
Maharashtra	Jalna,Beed,Nanded,Latur,Osmanabad,Sdholapur,Satara,Sangli,Kolhapur,Dhule,Jalgaon,Aurangabad,Ahmednagar,Pune,Buldhana,Amravati,Akola,Nagpur,Wardha,Bhandara,Chandrapur	948 (Nagpur)
Orissa	Bolangir,Jagatsinghpur,Cuttack,Angul, Malkangiri,Rayalpada,Baragarh,sambalpur,Sundargarh,Ganjam,Kalahandi, Nawapura and Keonjhar	800 (Ganjam)
Punjab	Bhatinda, Faridkot, Ferozpur, Patiala, Sangrur	900(Sangrur)
Tamil Nadu	Coimbtore, Periyar, Salem	1600 (Salem)
Rajasthan	Bikaner, Bharatpur, Jhunjhunu, Alwar, Ajmer, Jaisalmer, Jodhpur, Udaipur, Jaipur, Churu, Ganganagar, Bundi, Sawaimadhopur	3080 (Bikaner)
West Bengal	Malda, Birbhum, Murshidabad, Bankura, Nadia, Medinipur, Purulia, Howrah, Uttar Dinajpur	331 (Purulia)
Uttar Pradesh	Ghaziabad, Aligarh, Agra, Mathura, Mainpuri, Etawa, Kanpur, Jhansi, Banda, Jaunpur, Hamirpur, Nainital, Pilibhit	840 (Hamirpur)

The remedial methods available for removing Nitrate from drinking water are-

1. Reverse Osmosis
2. Ion Exchange
3. Bio remediation
4. Blending

Measures for Protection of Quality of Ground Water

With a view to foster better ground water management, especially quality at local and national levels, it is suggested that;

1. Regulation of ground water development should be enforced in critical areas.
2. Conjunctive use of surface water and ground water should be adopted.
3. Rainwater harvesting and artificial recharge should be adopted.
4. Development of deeper aquifers (uncontaminated and sustainable) with proper well design should be taken up.
5. Treatment of ground water with quality problem and stress on R & D related to scientific and proper disposal of industrial effluents, domestic and municipal sewages.
6. Regular monitoring of ground water quality to be carried out, especially in problematic areas
7. Public awareness programs should be organized periodically to make people and industry aware of the deterioration of quality and dwindling ground water resources.

COMMUNITY DRIVEN DECENTRALIZED GROUND WATER MANAGEMENT

Rajendra Singh*

Background

In Indian tradition, the knowledge was transmitted through practical work under the direction of respected elders and gurus. Thus the people engaged in practical work were really pupils of the indigenous knowledge system. The poor, the prosperous pupils, and the State joined hands for the conservation of water and the preservation of knowledge. The prosperous pupils provided help to the poorest, who were working for water conservation, and the State provided only land. It was a pupil-driven decentralized water management, which is another name for indigenous water management.

The lowest rainfall in India is in the arid regions of Jaisalmer and Barmer. There the people have in Tanka in every house for drinking and domestic use. They also have a pond (Talab) for common use and drinking water for animals. They also use Kuinya, for harvesting drinking water in the form of sand-moisture in the sub-surface, where the aquifer is brackish and separated from the above layers by a layer of Gypsum.

The ancient indigenous engineering was not much documented in the modern sense, because the technical aspects were transmitted through practice and words of mouth, and gradually perfected by tradition. But in some cases the Legal and Administrative aspects were written, for example in Kautilya's Arthasastra (Treatise of Administration written by Kautilya, advisor and minister of the first Indian emperor Chandragupta Maurya, 321-297 BC). One chapter of the Arthasastra gives a testimony of the very comprehensive and detailed administrative management, facilitated by the State. The ruler had to provide land, roads, trees and equipment to those who participated in the construction of waterworks. Those who did not participate were made to pay a contribution, but were not entitled to benefit directly from the structure. The methods of ownership and maintenance of new, ancient and repaired structures were described in details. All the users of irrigation facilities had to pay a tax, even when they had their own waterworks. But exemption of tax was granted for a number of years to those who build new structures.

However, these administrative rules were only safeguards and practical provisions for the economic consequences of the implementation of the waterworks. The real motivation came from the other side. The participation in construction of community ponds, tanks and waterworks was a matter of pride and religious devotion. The conservation of forests, water bodies and other natural resources in an extremely healthy state over the past thousands of years even under difficult climate and geographical conditions and with a growing population and demand, it was possible due to an extremely eco-friendly cultural traditions (dharma / parampara) of **"Live within what nature sustainably releases, don't be greedy"**. The traditional knowledge and practices of every area imbibed a thorough understanding of ecological balances and technologies to harness natural resources in a sustainable and eco-friendly manner, though these have never been documented. For centuries, the line of thinking that soil, water, forest, wildlife and the whole environment are a common asset of the local people bestowed by the Almighty to be managed as a "trust", was the commonly accepted worldwide. This age old balance has been disturbed at an accelerating pace in the last 200 years, and every revolution and

*Tarun Bharat Sangh, Alwar.

counter revolution has indeed increased the depth of the fall; the Industrial Revolution, the agricultural "Green Revolution", the "Development" Revolution, and now the "Privatization" and "Information Technology" revolutions.

The European colonizers brought the idea that Nature was to be "exploited", and undermined the feeling of responsibility for Nature. The modern State (colonial or independent) dispossessed the rural communities of their rights and responsibilities, and in the name of common good and conservation, has been bit by bit selling the forests and rivers, either legally (tree felling licenses, water rights) or illegally (corruption). The Education Revolution convinced the people that tradition and oral knowledge were causes of poverty. The "development" and socialist "welfare" post independence State, prompted the illusion that "everything has to be taken care of only and by all-powerful government, and now that the reality of its incompetence has become clear, the capitalist empires, MNC's and High Technologies (IT & GMO etc) are called to the rescue, most likely to result in further and deeper degradation. To make things even more difficult, the language itself has become corrupted. For example, the official Jargon for the most indisciplined water extraction is "ground water development", and educated engineers seem to re-discover the ancient tradition of responsible "artificial ground water recharge", ignoring the proved local traditions like Johads. Even to understand a traditional technology like the Tanka, they feel compelled to "improve" it, like using cement instead of lime, or RCC slabs instead of brick domes, thus degrading the tradition and its relevance, to the level of their limited understanding. The natural methods are not only forgotten, their vestiges are day after day more deeply dug into the ground. To sum-up the difficulties that we are facing can be categorized as such: Paradigm Change, exploitation and disintegration has taken the place of "feeling together" and integration. State takeover of Community Functions has dispossessed the Communities of their traditional rights and responsibilities.

Syndrome of Dependence

Wherever the State succeeded (even partially or for a short period) in implementing modern amenities like water supply, sewage and power the communities have lost their initiative.

Neglect of Traditional Systems

- Due to implementation or expectation of modern facilities, the traditional systems have been neglected.
- Disintegration of community institutions: The modern education and hollow dreams of modernity have disintegrated the community institutions.
- Incapability to cope up with increasing human and livestock population. The degradation of natural and social conditions has led to the inability of the communities to face the problems created by growing demand. The rural communities have lost their food and livestock security, their living conditions have become more difficult, resulting in forced migrations to big cities in search of survival in indecent and exploitative conditions.

Re-awakening the Indigenous Knowledge

Traditional Rain Water Harvesting Systems in India

There are various types of methods of Water harvesting in India. The common features of all systems are:

- Use of local resources and technology Community based operation
- Community driven decentralized water management, Sustainable use and conservation of our natural resources
- Revival of resources using indigenous knowledge
- Interventions understanding traditional systems and use of traditional
- knowledge
- Mobilization of community around land, water, and forest
- Participation in rejuvenating old structures and construction of new structures
- Creation of new village level and river basin institutions

How TBS has Revived the Tradition of Johad

On the night of 2nd October 1985, when I got down at the last stop of the bus at Bhikampura, with four of my friends, we only had a single agenda, which was "to fight injustice against people". We knew only one way to do it i.e. by spreading literacy in villages. So we promptly started a literacy drive. But the people suffered from a severe scarcity of water. The region that once sustained the eco-system of the "Aravali" had become barren. It was rare to find young people in the villages, all of them had fled in search of employment. Women trudged long distances to fetch a mere pot of water. Crops failed regularly, lack of vegetation led to soil degradation, monsoon runoff washed away the topsoil. I remember there was not a single blade of grass in the region and we often stumbled on the carcass of the cattle. Barely 3 percent cultivable land was irrigated. Life was difficult and hardship was endless.

One day Mangu Patel, the wise old man of this village told me, "We do not want your literacy, we want Water". But where was the Water? I did not know anything about Water. Mangu explained to me about the rich tradition existing in this region of building "Johads", which were a prime example of the ingenuity of inexpensive simple traditional technology that was quite remarkable in terms of recharging ground water of the entire region. "Johads" are simple mud and concave shaped barriers built across the slopes to arrest the rainwater run-off with a high embankment on three sides while the fourth side is left open for the water to enter. The height of the embankment is such that the capacity of the "Johad" is more than the volume of the runoff coming from the catchment based on a rough estimation of maximum possible runoff that could come into it. Therefore the height varies from one "Johad" to another, depending on the site, water flow, pressure etc. in some cases to ease the water pressure a masonry structure called "Afra" is also made for the outlet of excess water. The water storage area varies from 2 hectares to a maximum of 100 hectares.

The water collected in a "Johad" during monsoon penetrates into the sub-soil. This recharges the ground water and improves the soil moisture in vast areas, mostly down stream. The ground water can be drawn from traditional open wells, built and maintained by the villagers themselves without any input from outside. As the percolation process takes some time, depending upon the soil, depth of water etc., during this temporary period (sometimes several months), the water in the Johad is directly used for irrigation, drinking of animals, and other domestic purposes. The advantage of this structure is that apart from arresting and storing ground water, it checks soil erosion, mitigates the floods, and ensures water supply in wells even for several successive drought years, like we had here in the last 5 years. Also, during the dry season when water gradually recedes in the Johad, the land inside the Johad itself becomes available for cultivation. This land periodically receives good silt and moisture, and that allows growing crops without any irrigation. So the Johad does not take away any valuable arable land from cultivation. The distinctiveness of this structure is that it is based on simple and cheap technology with locally available resources, mostly labor and soil, and sometimes when necessary stones, sand and lime, all locally available. All the estimations are based on villagers experience and intuition, without any physical measurements.

When I went to Bhikampura in 1985, this unique traditional water management system was still alive in the collective memory of the people remained alienated from the global environment. On the advice of Mangu Patel, we became a catalyst to building "Johads". The local authorities were dead against us as we by-passed all bureaucratic channels and dealt with the people directly to fulfill their requirements in the manner they decided.

The first "Johad" took three years to build, in the fourth year we build 50 "Johads", in the fifth we build almost 100, and in 2001 we build around 1000 water structures and in total we have built nearly 8600 water harvesting structures in more than 1000 villages. When we started working, our area was classified by the government as "Dark zone", it means with severe water shortage and the water level had receded to difficult depths. The same area after 10 years was classified as "White zone", which means ground water levels are satisfactory and it does not need attention from the government.

No engineer was called for consultation; we were guided entirely by the traditional wisdom of the people who have maintained the ecological balance for generations. These water structures were built by active participation of the community in all stages, from identification of the site, designing and construction of the structure, contribution in the cost of its construction and later its maintenance, which ensured that all the structures were need based. As a result, water became abundant, more water gave better crops, better conditions of soil, time for girls to go to school and rich community life. It helped in forestation of the area and development of wildlife. Prosperity returned to the region, agriculture became productive and due to availability of fodder cattle rearing started, resulting in increased production of milk. Higher water levels also meant less money on diesel for pump set.

In 1985 only 20% of the agricultural land was cultivated, now it is 100%, and the villagers started selling grains in the market for the first time. Studies have shown that an investment of Rs.100 per capita on a "Johad" raises the economic production in the village by as much as Rs 400 Per Capita Per Annum. Ref: Small inputs, Great Return (1995) G. D. Agrawal (Ex Head Dept. of Civil Engineering IIT, Kanpur.)

As villagers mobilized themselves to improve their quality of life by contributing in building "Johads", this participation of people promoted the community to become self-reliant, optimizing social cohesion and emotive bonding in the community. Since people realized that members were responsible for not only individual but also for pro-active action, they became more aware of their rights taking on an activist stance to stop employment of children in the carpet industry and fought a legal battle up to the Supreme Court to stop indiscriminate mining on forest land.

An enlightened and active community also enforced self-discipline for the common good of the village. They strictly enforced their own rules to stop deforestation, hunting wildlife and consumption of liquor. The cultivation and irrigation tempted people to listen to TBS's idea of forming a River Parliament. The awareness built by various discussions, group meetings, trainings, exposure trips etc, also contributed in mobilizing and sensitizing community to form a group to address inter and intra village land, water and vegetation related issues and to resolve conflicts if any. Also events such as conflict between State and community in reaping benefits of water stored and conflicting claims over ownership and control of surface water harnessed through various structures triggered the idea of coming together and protecting the interests of the community.

Arvari Parliament

The concept of river basin approach was applied to Arvari River basin in Alwar district of Rajasthan using community centered water management approach. On Dec 28, 1998 a River Parliament of 70 villages with the membership of 205 was formed in the catchment area of Arvari River. The Parliament meets twice a year at the interval of 6 months. The Arvari Parliament has met 14 times since its formation.

Arvari River Basin has got 46 micro watersheds. There are mainly two major streams starting from the top of the basin and Joining at the dam called Sainthal Sagar. Tarun Bharat Sangh (TBS) is continuously constructing water-harvesting in the catchment area along with other watershed management activities. It resulted into rise in ground water table in the basin and increase in the longevity of in the Arvari River. Holistic view in management of natural resources by taking land, water and vegetation related activities was the objective of TBS. TBS tried to educate people on NRM issues by forming a Village Water Council in each village. The objective of this village institution was mainly to protect, conserve and manage the natural resources in a sustainable way by community participation. After long years of hard work these councils made a dent in the natural resource management by forming certain informal rules, acceptable to all village members. However, water and vegetation are common pool resource and do not belong to a single village as was contemplated while planning the Arvari River Parliament. More than one village had access to and use of forest and water resources. It was decided to form a River Basin Parliament comprising of several micro-watersheds. It was planned that each Village Water Council (VWC) would be represented by nominating two or three members in the Parliament. A working group of twenty members including few co-opted members from outside basin to guide the proceedings and activities of the Arvari Parliament was also proposed. It was planned to have at least two meetings of full house and more than two of Management Committee/ Working Group as and when needed. The main goal of this Parliament was to create a larger vision/perspective i.e. thinking beyond a village, in management of common pool resources. The specific objectives were;

1. Sustainable management of natural resources through Arvari Parliament,
2. Control usages of water by treating it as a scarce resource,
3. Managing the soil fertility and checking land erosion by construction of Anicuts, Mairbandhi and Johads,
4. Stopping illegal mining activity negatively affecting land, water and vegetation.
5. Generating self employment and alternate livelihood options through better management of land, water and forest resources,
6. Sensitizing and building awareness among women groups on water related issues and seek their active participation,
7. Increase agricultural productivity by growing water saving crops with local seeds and manure.

In the first meeting of the Parliament, certain guidelines were drawn to regulate the behaviour of people, foresee future problems in management of NRM, resolve conflicts if any, related to access and use of resources, provide guidelines for conservation, protection and management of resources, and treat water and forest as a community resource rather than private property. The specific informal rules formulated are as follows;

1. Ban on sale of Fish produced in water stored by Anicuts or Johads to contractor,
2. Ban on use of pumps to lift water from Anicuts,
3. Not to sell land for mining / quarrying or industrial activity,
4. Encourage people to grow water saving crops,
5. Restrict use of chemical fertilizer,
6. Limiting production of cotton and sugarcane crop only for self-consumption,
7. Construction of Mairbandhi to check degradation of farmlands and
8. The issues related to water, land and vegetation are to be dealt by combined effort of village community ensuring, maximum participation of households in a village.

The Organization of Parliament

The basin level institution created by TBS is expected to perform several roles such as;

a) To conserve water resources and emphasize on demand side management,
b) To ensure community control and management over water resources,
c) Equitable distribution of resources,
d) Provide equal access to all sections of the society,
e) Ensure sustainable use of water resource to protect interests of future generation,
f) To resolve conflicts if any, around water resources, and
g) To organize and empower people through natural resource management.

It was the part of the scheme to ensure equitable participation of women in all its activities and to see that they too are empowered in the process. In the organization structure, it was planned to have both men and women representatives. Presently women are participating actively in all its activities

Being a very young organization all these above listed objectives were only partially addressed. Different stakeholders are taking a lot of time to understand the concept of River Parliament and get in practice. As it requires change in the perception from individual, private, narrow profit maximization approach to broad, village and basin level community approach to water resource management. People gradually understand the benefits of coming together and managing water resources. So far they were having all freedom to use land, water and forest resources to meet not only domestic requirement but also derive livelihood at the cost of complete degradation or deterioration of natural resource. The social sanctions approved by the Parliament are adhered by most of the villagers. It has made lot of dent on their behavior towards natural resource management. Arvari Parliament has provided people a platform to address their needs, prioritize them and design use patterns, which can maintain health of resources. It has also provided opportunities for young local leaders to come up and safeguard the interests of the community. The discussions in the meetings of the Arvari Parliament are quite open providing equal opportunities both for men and women to express their views. Despite all these benefits there are objectives yet partially attended. It is not that people do not want to address those issues but the process of evolution in any institution takes a lot of time and energy to arrive at major issues of equity and access of in use of natural resources. There were traditional norms for sharing water from a well in case of joint ownership. They are still in practice. The major problem in attaining the objectives of equity and access is the multiple and undefined nature of property regimes. The ownership and control rights are loosely defined, rarely understood in proper perspective and practiced. In case of water, surface and ground water, are governed by different laws related to private property, state property and community property.

Ground water is completely privately controlled and managed

On the other hand surface water harnessed by the construction of structures by both state and community are legally owned by the state. Also water laws are directly in favour of government and people are mostly unaware of these laws. Ground water is treated as private property and therefore used in a fashion to maximise individual profits at the cost of Over exploitation of the resource to the extent that has negative environmental impact. However, in case of forest resources ownership rights are clear and therefore, better managed by community as compared to water resources.

Impact of Arvari Parliament

There are direct and indirect impacts of Arvari parliament. These can be categorized into three broad aspects namely, Physical, Economic and Social.

In the category of Physical impact, it is mostly the protection of water resources, increase in areas under cultivation, improvement in quality of land and forest resources and most important of all is physical community control over land, water and forest resources.

Economic impact is largely manifested in change in livelihood pattern because of improved access to water resources in general and ground water specifically. Increase in water availability has led to several commercial activities such as production of Tomato and other vegetables increase in employment and trade activities. Because of increase in agricultural production (both commercial and other nature), marketing activities came up in a big way, exporting produce from river basin to metropolitan cities, establishment of commercial states and activities of middle men and other businessmen dealing with produce, transport activity, emergence of services such as agro-service centers, commercial shops, Dhabhas, tea stalls etc. This has also led to diversification in livelihood activities. Several livelihood alternative activities came up which has engaged large number of population and stopped them from migrating outside in search of jobs.

The Social impact is quite significant as the Arvari parliament empowered people to fight for their claims over resources, question state bureaucracy about their programmes and plans, and led to better implementation of plans at ground level. Further it also helped in drawing plans for future use of natural resources. It is particularly the women who had no chance to put forward their views and opinion in any of the policy matters or activities in a village got a platform to represent their case. Now they are participating in all the activities organized at village or basin level.

It is also important to note that Self Help Groups formed by women are all active and doing well compared to the failure of groups formed by men. Women SHG's have changed the status of women in household activities and decision making.

Strengths and Weaknesses of the Institution

Arvari parliament has major strength in associating all sections of the society from all the corners of the catchment area. This has generated social capital in a big way. Participation of women in all activities and at different scales has empowered women groups in the areas. The parliament has the capacity to plan and mobilise physical and financial resources to undertake works in the basin. People have contributed 25 to 80 percent in different community structures. It has its own regulatory mechanism to control pattern of resource use. It has also provided a platform to resolve conflicts arising in management of land, water and vegetation in the basin. It is all because of the fact that people based on their felt need to manage natural resources themselves, rather than imposed from above/outside created this institution.

As the institution is young and is in the phase of evolving norms for sustainable management of natural resources in the basin there are a few weaknesses also. The strength of this Parliament depends largely on the strength of the Village Water Councils and participation of the people. Though realizing the fact that presence of Arvari Parliament will benefit all sections of the population, there are certain interest groups, supporters of privatization and state hierarchy that tries to create obstacles in the smooth functioning of the Parliament. It is largely because of the fractured nature of society created by state and bureaucracy in the last 50 years of independence.

Challenges Faced by the Arvari Parliament

There is a lack of clarity regarding Ownership and Responsibility for Water Harvesting Structures and resulting Water Structures. The Arvari Parliament attempts to revive ancient tradition of community responsibility towards Common Resources, in a difficult legal and administrative environment, with its impractical and counter-productive provisions, which lets the so-called "owner "of a plot of land, to do virtually anything with the soil and water, including for example emptying the whole aquifer or polluting the soil for ever, but which puts a lot of obstructions in the way of any initiative for community-based management of common resources. One of these obstructions is the Irrigation and Drainage Act; 1954, which does not recognize the indigenous Water Management System.

In all this, volunteer of TBS functions as facilitator with *Gram Sabhas* and their leaders. This is very important and is a product of one's contribution, participation and sharing.

The Use of Indigenous Knowledge in TBS work

- Awareness in the community regarding various aspects of water management.
- Respect for culture, traditions and historical practices.
- Will to work together for community's common interest.
- Working strategy is to draft constitution of village councils.
- To ensure the compliance of the constitution monthly meetings of all groups are conducted.
- Maximum possible use of traditional knowledge with advice from engineers if needed.
- All decisions (including technical, i.e., site selection, materials, designing etc) are taken by Gram Sabhas.
- All decisions by consensus, not by majority.
- Role of women in reaching consensus is important for TBS.
- Min 30% of total cost is to be contributed by Community. Rest from support agencies through TBS.
- Total responsibility of operation and maintenance is assumed by the community.
- Water abstraction and use water management; there is a river parliament (Arvari Sansad) with all 72 villages of the Arvari basin. It is responsible for

planning and enforcing sustainable use of water, particularly in agriculture.
- Re-awakening the traditional transmission of indigenous knowledge is to be executed through "Tarun Jal Vidyapeeth."

After having run 9 month training for its own volunteers for many years, Tarun Bharat Sangh has started this year a professional school of water named as Tarun Jal Vidyapeeth. The Vidyapeeth offers different courses open to all and specifically designed to fulfill the needs of young village boys and girls. The course design process itself involves the active participation of the students, to ensure a "need based" course and their full commitment and responsibility for the revival of the indigenous knowledge of water management.

ARTIFICIAL RECHARGE OF AQUIFERS

S.C. Dhiman*

Introduction

Ground water is the most dependable source for various uses of water in rural and urban areas. Over the last four decades, increase in abstraction of ground water through tube wells / bore wells to meet the rising water demand for domestic, industries and irrigation has raised concerns regarding the sustainability of the resource and the livelihoods it supports. Continuously declining water level trends have been observed because of excessive withdrawal of scarce ground water resources in certain pockets of the country.

Artificial recharge of aquifers is defined as augmentation of ground water resources, brought about as a result of man’s activities. It is carried out to hold surface runoff and encourage infiltration to aquifers through the construction of suitable recharge structures. Aquifer recharge is applied for enhancing ground water resource which can be utilized for various purposes by the society.

Objectives and Benefits of Artificial Recharge to Aquifers

Artificial recharge to aquifers is a water resource management strategy and applied in specific areas with the following objectives;

i) To stabilize or raise ground water levels in over-exploited areas,
ii) Reduce losses through evaporation and runoff,
iii) Arrest flood / storm runoff and soil erosion,
iv) Maintain longer flows in streams/rivers/spring,
v) Rejuvenation of dry rivers / springs,
vi) Arrest saline water ingress in fresh water aquifers inland and coastal areas and
vii) To reduce the gap between supply and demand of ground water.

Need for Scientific Inputs for Efficiency of the Recharge Projects

Detailed knowledge of geological and hydrological features of the area is essential for selecting the site and type of recharge structure. Hydrometeorological studies are important to decipher the rainfall pattern, evaporation losses and other climatic features. The data on rainfall intensity, number of rainy days etc. help in deciding the capacity and design of the artificial recharge structures. Before undertaking a recharge project, it is necessary to ascertain the availability of source water for the purpose of recharging the ground water reservoir. The success of an artificial recharge project depends largely on the local hydrogeological set up and the ability of aquifers to store the recharged water. In case of artificial recharge through surface techniques, soil and land use conditions, which control the rate of infiltration and downward percolation of the water, assume special importance. The maps providing information on regional hydrogeological units, their ground water potential and general pattern of ground water flow / fluctuations and chemical quality of water in different aquifers are necessary. Remote Sensing and Geophysical techniques are also used as supplementary tools to narrow down the target zone, pinpoint the probable site for artificial recharge structure and its proper design. The geophysical methods are also utilized to identify the brackish - fresh ground water interface, contaminated zone and areas prone to saline water ingress.

*Member, Central Ground Water Board.

Rural Areas

Ground water resources are abstracted mainly for irrigation and drinking purposes in rural areas. In areas where majority of irrigation is dependant on ground water resources, ground water levels show declining trend in long run unless replenishment of the aquifers takes place simultaneously. Excessive withdrawal of ground water is generally not balanced through natural process of recharge and aquifers need to be recharged artificially. Feasibility for construction of artificial recharge structures depends on various factors such as:

* Rock / soil type / geomorphology
* Landuse classes / Irrigation pattern / Type of crop / cropping pattern
* Network of canal (lined/unlined) / natural drainage (ephemeral /perennial)/ surface water bodies
* Hydrogeological properties of aquifer and overlying formations
* Physical and hydraulic boundaries of the aquifers
* Number of ground water extraction structures / withdrawal rate/ water quality / water level and fluctuation rate / flow directions
* Availability of surplus water and demarcation of catchment area for recharge site, selection of recharge structure and its design.

Urban Areas

In Urban areas, with increasing demand of water, pressure of ground water resources has increased tremendously. Ground water is abstracted by the water supply agencies, industrial units and individuals as per their need, whereas natural recharge in urban areas has decreased significantly due to urbanization and change in land use practices. Even open area for constructing recharge structures is not easily available now a days in urban areas. The factors need to be considered for selecting feasible sites for recharge structures in urban areas are indicated below:

* Lithology, structures and geomorphological features in the area
* Land-cover and land-use classes / drainage, lined/unlined drains
* Availability of surplus water / rain runoff
* Demarcation of landfill, sewage treatment plants and industrial sites
* Use of ground water, extraction pattern, quality, water level and fluctuation rate, flow direction, fresh–saline water interface
* Selection of buildings with larger roof area and design of structure.

Selection of Source Water for Artificial Recharge

The availability of source water is one of the prime requisites for ground water recharge. Four types of source water may be available for recharge viz.

1. In situ precipitation on the watershed.
2. Surface water supplies from perennial / ephemeral rivers, lakes / ponds or reservoirs located within the basin.
3. Surface supplies through canal system from another basin
4. Treated municipal and industrial wastewaters

Surface water is generally the prime source of recharge water. Most of the times, the water of the ephemeral rivers are diverted or slowed down by constructing barriers. Runoff in ephemeral streams generally carries considerable quantities of silt in suspension depending on land cover and the turbulence which can cause clogging if water is used directly in recharge facilities. Settling ponds are, therefore, recommended before water enters infiltration pond / chamber. Water from perennial rivers is also diverted to nearby recharge facilities or channelised to distant recharge facilities depending upon the conditions of source water availability and need for recharge in the area. In hilly and snow bound areas (cold arid regions), snow harvesting is also practiced to recharge the aquifers by storing the snow in artificially created fields to give sustainability to springs existing downstream. This is commonly practiced in Ladakh region in Jammu and Kashmir.

Urban areas generate significant quantities of rain water runoff which can be utilized for the purpose of artificial recharge to aquifers. This runoff is highly variable in quantity with peak discharges occurring after heavy rainfall in arid, semi arid and humid climate areas. In arid areas, net precipitation rate is low, rainfall events are infrequent / short duration and mostly high intensity storms bring a major portion of the annual rainfall to the surface during a very short period of time. Hence, water availability in such areas is sporadic and highly variable in intensity. For managing runoff in such areas, techniques to modify watershed surface, storage capacity and recharge methodology would be different from those to be applied in humid climate. In order to obtain a more consistent supply, infiltration and storm-water retention ponds, grassed areas and porous pavements are recommended. The best quality runoff water in urban areas is from rooftops and increasingly initiatives are being made to direct this water immediately to ground water recharge through infiltration galleries, wells and boreholes. This not only replenishes urban aquifers that are often over- exploited, but also introduces good quality water in dynamic ground water resource.

Rural areas having large open areas generally generate huge surface runoff from agricultural fields as well as from uncultivated land during intense rainfall. This runoff can also be channeled into hand-dug wells to recharge the aquifer directly. Such practices are common in some parts of Saurashtra Region in Gujarat State and have shown encouraging rise in water levels and longer period availability of water for irrigation. The contaminant load in rural runoff from agricultural lands have the possibility of including residual pesticides and fertilizers as well as faecal matter from livestock, human and other sources. Recharging of such runoff directly into the aquifer has the risk of contamination of aquifer.

Identification of Sites for Artificial Recharge

Implementation of artificial recharge projects are generally site specific and even the replications of the techniques for similar areas need to be modified on the basis of local hydrogeological and hydrological environments. The artificial recharge of ground water is normally taken in the areas for following reasons:

i. Ground water levels are declining on regular basis.
ii. Substantial amount of aquifers has already been desaturated.
iii. Availability of ground water is inadequate in lean months.
iv. Salinity ingress is taking place inland or coastal zone.
v. Ground water source is contaminated

Ground Water Scenario and Recharge Practices in India

Indian subcontinent has a wide spectrum of physiographic, hydrogeological and hydrometeorological features varying from snow clad mountains in the north to desert in the west with a coast line of more than 6000 km. Average annual precipitation over the country is about 4000 BCM. Due to tropical climate and its geographic location, the country experiences vast spatial and temporal variations in precipitation. About one-third of the country's area is drought prone. The hard rock area predominates in the States of Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Rajasthan and Gujarat and is drought prone, whereas Uttar Pradesh, Bihar, west Bengal and Assam experience periodic floods. Major river basins have annual average runoff of about 1869 BCM. The average annual utilizable surface water is 690 BCM and a vast amount of runoff joins sea.

Total annual replenishable ground water resource of the country has been assessed as 432 BCM. The country has experienced accelerated development of ground water resources in last quarter century, being reliable resource accessible to all. Easy accessibility to ground water resource has led to its widespread exploitation in rural and urban areas of the country. Net annual ground water availability is 399 BCM and is annual ground water draft is 230 BCM in the country. The States of Tamil Nadu, Andhra Pradesh, Karnataka, Madhya Pradesh, Maharashtra, Punjab, Haryana, Gujarat and Delhi have large number of over exploited and critical blocks (assessment units) where ground water development is extensive and can not be overlooked. Ground water is essential for sustainable development of the country and it is necessary that runoff is harvested and recharged to aquifers through suitable techniques of artificial recharge to arrest continuously declining water levels and depleting ground water resources in major part of the country.

Rainwater harvesting and recharge are the options for management of depleting ground water aquifers. Traditionally, in our country, there is practice of harvesting rain runoff through Talab, Johads, Paar, Rapat, Bandha, Kunds and Kuis in Rajsthan; Khandins in Gujarat, Jampois in West Bengal; Cheruvu in Andhra Pradesh; Kohlis and Bandharas in Maharshtra, Zings in Ladakh, Kul and Khatri in Himachal Pradesh; Eri in Tamil Nadu; Surangam in Kerala and Ooranies in Travancore. With the pace of tremendous development in various water using sectors, the stress on ground water resource has increased with the effect that many areas in southern and western parts of the country are experiencing continuously declining water level trends, drying of aquifers and saline water ingress.

Experiments on artificial recharge to aquifers started in India from 1970 onwards by Central & State Governments and individually by NGOs in various parts of the country where early signs of overexploitation of ground water were noticed. The Central Ground Water Board undertook artificial recharge experiments through injection well around Kamliwara in Central Mehsana where sufficient water was available from Saraswati river during monsoon period. A detailed injection experiment was carried out at the Kamliwara site by injecting water from the source well in Saraswati riverbed to the injection well by 5cm dia. siphon of galvanized pipe, at a rate of 225 m^3/day for 250 days. There was a buildup of 5 meters in the injection well and 0.6 to 1.0 m in wells in areas 150 m away. These experiments indicated the feasibility of ground water recharge through injection well in the area.

Similarly spreading test through channel and recharge pit were carried in coastal areas of Saurashtra, Gujarat. The Board undertook another artificial recharge study in the Ghaggar river basin with the assistance of UNDP during the period 1976-78 at Kandi area and Narwana Branch area, Dabkheri and indicated area as suitable for recharge through ponds and spreading basin in Kandi area and through injection wells at Narwana.

Several experimental recharge and rainwater harvesting pilot projects were carried out at Saurashtra, Ahmedabad city and Kutch in Gujarat, farm rain water management at Raipur, Percolation tanks/check dams in Andhra Pradesh, Percolation channels and Bandharas in Maharshtra, subsurface dykes in Kerala, roof top rain water harvesting and recharge in urban and hilly areas by the Board, State Governments and Non Government Organisations. In Eighth Plan, the Central Ground Water Board carried out recharge studies at Watershed TE-17, Yaval taluka and Watershed TE-11 in Jalgaon and Watershed WR-2, Warud Taluka, Amrawati in Maharshtra and Percolation tanks and roof top rain water harvesting in Karnataka where rise in water level up to 10 meters was noticed benefiting area by increase in crop intensity annually.

Pilot artificial recharge studies in different hydrogeological and agro-climatic set ups to develop model recharge structures were taken by the Board in Ninth Plan. Pilot Projects were taken up in areas of over exploited, dark, grey blocks or affected by ground water pollution / salinity ingress having surplus monsoon runoff and sufficient subsurface storage. Roof top rain water harvesting and recharge studies were also taken up in hilly terrain like Jammu & Kashmir, Himachal Pradesh, Assam, Meghalaya, Nagaland, Mizoram and other hilly regions which generally face scarcity of even drinking water during lean period. Pilot projects were implemented in close co-ordination of State Governments Organizations. The scheme has helped in creating awareness for rainwater harvesting and artificial recharge to ground water in the country. The pilot recharge projects enhanced the sustainability of drinking water sources, created additional irrigation potential and increased agricultural productivity locally.

Recharge Techniques and their Implementation in Various Parts of the Country

Flooding

Flooding technique is useful in areas having favorable hydrogeological situation for recharging the unconfined aquifer by spreading the surplus surface water from canals / streams over large area for sufficiently long period of time so that it recharges the ground water body. Water recharged to ground water can be pumped out during summer. A pilot project was implemented at Chetua to Jamuna, Pandua block, Hoogly district in West Bengal by the Central Ground Water Board in IX plan.

Recharge Basin or Percolation Tanks

Recharge basins are either excavated or enclosed by levees. In alluvial areas, multiple recharge basins are generally constructed parallel to streams for recharging purposes. Percolation tanks generally have bunds with large reservoir areas. Percolation tanks are artificially created surface water bodies submerging a highly permeable land area so that the runoff is made to percolate and recharge the ground water storage. At places, vertical shafts are also constructed in percolation tanks to enhance the recharging process.

Such structures for recharging are constructed at Watershed TE-11 Jalgaon district, Maharashtra, at Chirakulam in Kottayam district, Kerala, Sikheri village and Tumar watershed in Mandsaur & Dewas districts Madhya Pradesh, Narasipuram in Alandurai watershed, Thondamuthur and Vedapatti village in Virdhunagar district of Tamil Nadu and in Mahboobnagar district, Andhra Pradesh in central sector scheme of recharge. Recharging of aquifers through percolation tanks in above projects has shown encouraging results during impact assessment studies (Table 1).

Table 1: Impact Analysis and Results of Artificial Recharge through Percolation Tanks Constructed under Central Sector Scheme.

Name of the scheme	Percolation Tanks constructed	Cost (Rs. in lakhs)	Additional recharge (TCM)	Rise in water level (m)	Area benefited (ha)
Watershed TE-17, Yaval Taluka, Jalgaon districts, Maharshtra	6 nos.	23.55	681	1-5	545
WR-2 Warud Taluka, Amravati district, Maharashtra	3 nos	76.98	298	4-10	280
Artificial recharge studies in Kolar districts Karnataka	1 nos.	10.35	sustainability to abstraction structures increased	1 to 3.5	Crop intensity increased (2 to 3 crops annually)
Watershed TE-11, Jalgaon, district Maharashtra	2 nos.	26.60	38	0-1m	150

Gully Plug / Check Dam/ Nala Bund / Gabbion Structures

Gully Plugs, the smallest runoff conservation structures built across small gullies and streams conserve runoff and enhance recharge locally during rainy season. The sites for gully plugs are chosen wherever there is a local break in slope to permit accumulation of adequate water behind the plugs. Check dams / plugs, small bunds or weirs are also constructed across selected nala sections to impede the flow of surface water in the stream channel for allowing longer period of recharge through channel bed. Nala bunds and check dams are constructed across bigger nalas of second order streams in areas having gentler slopes. To harness the maximum runoff in the stream, series of check dams are constructed to have recharge on large scale in watershed. A nala bund is a small earthen dam which acts like a mini percolation tank. Gabbion structure is low height check dam commonly constructed across small stream to conserve stream flow with practically no submergence beyond stream course. The boulders locally available are stored in a steel wire mesh and put across the stream channel as a small dam by anchoring it to the streamside. The excess water overflows these structures storing some water to serve as source for recharge.

The Board has implemented artificial recharge projects by constructing such structures through state government agencies at Ayandikadayu, Chirayanki district, Kerala; Kadam nala, Pusaro nala, Brahmani nala and Tepra nala in Dumka district, Jharkhand; Gwalpahari, district Gurgaon, Haryana; Thano reserved forest area, Doiwala block, Uttarakhand; Chalokhar in Hamirpur district , Bhatti nala, Suhal nala and Naker khad in Kangra district of Himachal Pradesh; Dewal in Kathua district, J&K; Parol naggal & Chotti bari naggal of district Ropar in Punjab; Bangalore university campus in Karnataka. Substantial impact on augmentation of ground water has been noticed in areas around these structures (Table 2).

Injection Well

Injection well is a recharge well similar to tube well but made with the purpose of augmenting the ground water storage of a confined aquifer by pumping-in treated surface water under pressure. Injection well is generally opted when land is scarce, as in urban areas. The aquifer to be replenished is generally over-exploited by tube well pumpage and has declining trend of water level. At certain places, because of the confining layers of low permeability, the aquifers do not get natural replenishment from the surface and need direct injection of water through recharge well. Artificial recharge of aquifers by injection recharge wells is also suitable for coastal regions to arrest the ingress of sea water and also to combat the problems of land subsidence in areas where confined aquifers are heavily pumped. For implementation of injection well recharge to aquifers, it is important that the geometry of the aquifer and the actual location and extent of recharge should be known so that water can also be pumped from those places during the time of need. Water for recharging is to be properly treated for removal of suspended material, chemical stabilization and bacterial control. Chlorination of recharge water can also be done to prevent development of bacterial growth. The injection well is to be periodically redeveloped for efficient running.

Recharge Wells/Dug Well Recharge /Borehole Flooding

Ordinary bore wells, tube wells and dug wells can be used as recharge wells, whenever surplus water is available. In such cases recharge takes place by gravity flow. In areas where water levels are declining due to over development, using available abstraction structures for recharging aquifers is the immediately available option. In areas of heavy ground water exploitation, the dug wells and shallow bore wells often get partially or fully dried up during summer. The rock material exposed in these wells is permeable and the unsaturated horizon of phreatic aquifer can be good repository of water if recharged with surplus available water. These wells can be used for pumping as well as for recharging process.

A project of roof top rain water harvesting through dug well recharge at Kavikulguru Institute of Technology and Science (KITS), Ramtek, Nagpur district, Maharshtra has been implemented. An area of 20 hectare had been benefited by storing 8000 cubic meters of water annually in addition to existing resources through this pilot scheme.

Recharge Pits/ Trench and Shafts

It is observed that phreatic aquifers are not always hydraulically in connection with the surface water. Generally on a regional scale impermeable layers or lenses form barrier between the surface water and water table, and thus the water spreading methods show low efficiency in recharge. For effective recharge of the aquifers, the less permeable zones are required to be penetrated so that the aquifer zones can receive recharge. Recharge pits overcome the difficulty of artificial recharge of phreatic aquifer from surface water sources. Recharge pit is excavated sufficiently deep to penetrate less permeable strata. In recharge pit, water does not directly allowed to mix directly at water table but infiltrated through the vadose zone. In many recharge pits infiltration occur laterally through the wall of the pit, because in most layered sedimentary rocks or alluvial sediments, the lateral hydraulic conductivity is considerably larger than the vertical. Recharge trench is a special case of recharge pit, in which some times bore wells are drilled to increase its recharge capabilities. In case aquifers are located below the land surface and overlain by poorly permeable strata, a recharge shaft similar to a recharge pit but much smaller in cross section is constructed.

Table 2 Impact of Recharge through other Recharge Structures (Check dam/ Nala bund/ Cement Plug & Subsurface Dyke)

Name of the scheme	Structures constructed	Cost (Rs. in lakhs)	Additional recharge (TCM)	Rise in water level (m)	Area benefited (ha)
JNU, IIT and Sanjay Van, NCT Delhi.	4 nos.	43.58	75.72	0.33 to 13.70	75
Watershed WR-2 Warud Taluka, Amravati district, Maharashtra	Cement Plug-10 nos.	9.32	46.743	0.5 to 4	86-105
Recharge in Purulia I,II, Main bazar and Jhalda blocks, Purulia district, West Bengal	10 farm ponds 8 nala bunds 2 subsurface dykes	50.54	65	0.15	28
Subsurface dykes for improvement of watershed in Saltora block, Bankura district, West Bengal	Subsurface dyke Gully plug Nala bund Farm pond	0.99	2.6	0.45	195

The recharge structures like lateral shafts with injection wells have been constructed on experimental basis at Deoli Ahir, in link channel of Hasanpur distributary in Mahendergarh district, Panipat district and near Markanda river in Shahbad block of Kurukshatra district in Haryana State as pilot recharge projects. Similarly Recharge pits with recharge shafts have been constructed at Lodi garden, New Delhi, at Choe no. 1 Bhakhara main line canal village Dhanetha , Samana block, Patiala and on Dhuri drain in Sangrur district, at low dam in village Majra, Tehsil Kharar in Ropar district in Punjab State. Recharge trenches with bore wells have been constructed in Midjil mandal in Mehboobnagar district in Andhra Pradesh and in Taliparamba taluk, Kannur in Kerala. Impact analysis of such projects indicated favorable recharging results (Table 3).

Induced Recharge from Surface Water Sources

It is an indirect method of initiating recharge by pumping from aquifer hydraulically connected with surface water to induce recharge to ground water reservoir. When the cone of depression intercepts river recharge boundary, a hydraulic connection gets established with surface source which starts providing part of the pumpage yield. For obtaining very large water supplies from river bed / lake bed or waterlogged areas, collector wells are constructed. Such wells have been installed in river beds at Delhi, Gujarat, Tamil Nadu and Orissa. The large discharges and lower lift heads make these wells economical even if initial capital cost is higher as compared to tube well. In areas where the phreatic aquifers adjacent to the river are of limited thickness, horizontal wells are more appropriate than vertical wells. Collector well with horizontal laterals and infiltration galleries get more induced recharge from the stream.

Table 3 Impact Assessment of Recharge Projects of Combination of Lateral Shafts / Recharge Trench / Injection Well for Artificial Recharge

Name of the scheme	Structures and numbers	Cost (Rs. in lakhs)	Rise in water level (m)	Remarks
Artificial Recharge from Dhuri link drain, Dhuri Block, district Sangrur, Punjab	Lateral shaft 250 meter length with three injection wells & 28 vertical shafts	34.20	0.22 to 1.38	Average rate of recharge through the Dhuri link drain is 16.51 lps
Artificial recharge from Dhuri drain II, Dhuri block, Sangrur, Punjab	10 lateral shaft, 20 shafts & 30 injection wells in 295 meters lateral shaft	39.10	0.15 to 0.33	Average rate of recharge through the Dhuri link drain is 94 lps
Artificial recharge in D.C. Office, Faridabad, Haryana	Recharge trench with injection well-(2)	1.70	significant	Rise in water level
Roof top rain water harvesting at Shram Shakti Bhawan, New Delhi	Recharge trench-(3) Injection well-(2)	4.1	0.3 to 0.5	Local rise in water level
Artificial Recharge Scheme for President Estate, New Delhi.	Recharge shafts=(3) Recharge through existing Dug well =(1)	12.73	0.1 to 0.9	Local rise in water level

Subsurface Dykes/ Underground Bandharas

Subsurface dyke is a subsurface barrier across a stream which retards the natural subsurface / ground water flow of the system and stores water below ground surface to meet the demand during the period of need. The main purpose of ground water dam is to arrest the flow of ground water out of the sub-basin and increase the storage within the aquifer. In Maharashtra State, ground water dams are called by the name of Underground Bandharas and widely used as water conservation measures. Subsurface dyke and check dam cum underground dams have been constructed by the Central Ground Water Board and their benefits are indicated in Table 4.

Roof Top Rainwater Harvesting and Aquifer Recharge

In urban areas where open land is not commonly available, roof top rain water can be conserved and used for recharge of ground water. This approach requires connecting the outlet pipe from roof top to divert the rain water to either existing wells / tube wells / bore wells or specially designed recharge trench / recharge shaft cum bore well. Drain pipes, roof surfaces and storage tanks should be constructed of chemically inert materials such as plastics, aluminium, galvanized iron or fiber glass, in order to avoid contaminating the rainwater.

Table 4 Benefits of Subsurface Dyke to Raise & Conserve Ground Water in Some Recharge Projects Implemented by the Board in Ninth Plan.

Name of the Scheme	Structures constructed	Benefits
Construction of subsurface dyke at Ayilam in Trivandrum district, Kerala.	Sub Surface dyke=(1)	5 thousand Cubic meter was stored in the upstream side and 2m rise water level
Construction of Sub Surface dykes at Kasrawad, district Kahrgone, Madhya Pradesh.	Sub-surface Dyke=(3)	rise in water level in dug wells in vicinity of subsurface dyke
Subsurface dykes constructed for improvement of watershed in part of Saltora block, Bankura district, West Bengal	Subsurface dyke Gully plug	Area benefited 195 hectares
Construction of subsurface dyke at Nallanpillai Petral village, Villupuram, Tamil Nadu	Sub-surface dyke=(1)	222 thousand cubic meter / Year runoff recharged & additional 29.39 ha. Irrigated
Subsurface dyke and related structures at Walmi Farm, Madhya Pradesh	Subsurface dyke, contour trenching and nala bund	Significant rise in water level locally

Urban housing complexes, historical forts and institutional buildings generally have large roof area and can be utilised for harvesting roof top rainwater to recharge the depleted aquifers. More than 50 roof top rain water harvesting and recharge projects have been implemented by the Central Ground Water Board at Delhi, Chandigarh, Jaipur and Udiapur in Rajasthan, Kangra in Himachal Pradesh, Ahmedabad in Gujarat, Kannur in Kerala, Patna in Bihar, Lucknow in Uttar Pradesh, Dewas and Musakhedi in Madhya Pradesh and Gurgaon and Faridabad in Haryana State. The outcome of impact assessment of schemes of roof top rainwater harvesting implemented in various States is given in Table 5.

The impact of recharge through these structures to ground water regime is local, but if implemented on a massive scale, it can raise the water level remarkably and increase the sustainability of water supply through shallow depth ground water structures. Roof top rainwater harvesting is practiced by 600 households in Dewas city, Madhya Pradesh, in which the Board has provided recharge filters as incentive to public for adopting this technology. The mass implementation of this technology has resulted in significant rise in ground water levels and revival of dry dug wells and

Table 5 Impact Assessment Analysis of Roof Top Rainwater Harvesting Projects Implemented by the Board in 9th Plan.

State	Scheme	Impact assessment
Assam	Rain water harvesting in Selected areas of Sonapur Block & Guwahati Area of Kamrup district, Assam.	55 TCM runoff was recharged in one year
Chandigarh	Scheme for Artificial recharge to ground water in Shantikunj area sector –16 (Leisure Valley) Chandigarh.	3466 TCM rain water was recharged in one year
Chandigarh	Scheme for utilising surplus water monsoon runoff for sector 26,27,19,30,20, Chandigarh.	966 TCM of rain water was recharged in one year
Delhi	Artificial Recharge Scheme for President Estate, New Delhi.	Water level rise 0.94 to 2.32 meters
Delhi	Scheme for rain water harvesting in Shram Shakti Bhawan,New Delhi	Water level rise 1.42 to 2.17 meters
Delhi	Scheme for artificial recharge to ground water at Prime Minister's office, South Block, New Delhi.	5 TCM of rain water was recharged in one year
Delhi	Scheme for artificial recharge to ground water at Vayusenabad, Air force station, Tughlakabad, New Delhi.	16.4 TCM of rain water was recharged in one year
Lakshadweep	Scheme rain water harvesting/artificial recharge in the U.T. of Lakshadweep Islands/Tribal Area Kavaratti Island.	3 TCM rain water harvested one year
Madhya Pradesh	Scheme for roof top rain water harvesting for Dewas City, Dewas district, M.P.	People's participation. Increase yield of tube wells and improvement in ground water resource despite deficit rainfall.
Maharashtra	Roof top rain water harvesting in dug well at KITS campus, Ramtek, Maharashtra	Water level rise and increase in discharge in nearby wells has been observed
Meghalaya	Scheme for roof top rain water harvesting in Shillong city, Meghalaya	6.8 TCM water harvested in one year
Nagaland	Roof top rain water harvesting in Mokokchung Town, Nagaland.	24.786 lakh litres storage capacity created in 4 fillings benefiting 551 households
Punjab	Pilot Scheme for Roof Top Rain water harvesting to recharge ground water in Kheti Bhavan, Amritsar town, Punjab.	474 cubic meter of rain water was recharged
Rajasthan	Roof top/ pavement rain water runoff harvesting structures at State Secretariat, Jaipur.	2.8 TCM of rain water recharged in one year

bore wells in a large part of the city. Roof top rain water harvesting is also suitable for direct use of water in hilly areas. Such water can be used for consumption only after the initial runoff from rain shower is allowed to run as waste to flush out accumulated dirt from the collection area and gutters and later collected runoff is to be filtered, chlorinated and disinfected before use.

Sum Up

Artificial recharge is a solution for the sustainable management of ground water resources in areas where component of the water supply and rainfall variability do not allow sufficient level of aquifer recharge by natural means. Performance of artificial recharge structures depend upon many factors such as type of terrain, rain fall intensity, infiltration capacity of soil, location of feasible site etc. It is essential that engineering knowledge is integrated with meteorological, hydrological and hydrogeological information of the watershed for effectively implementing the artificial recharge to aquifers. The artificial recharge to aquifers is environmental friendly technology which significantly increase sustainable yield of aquifers. Application of artificial recharge methodologies is easy to understand by both the technicians and the common man for construction, operation and maintenance. Awareness for implementation of this technology need to be widely publicized.

GROUND WATER REGULATION

S.C. Dhiman*

Introduction

The importance of ground water for the existence of human society cannot be overemphasized. Ground water is the major source of drinking water in both urban and rural areas of India. Besides, it is also an important source of water for the agricultural and the industrial sectors. The users take it as most dependable resource. The demand for water has increased over the years in various sectors leading to water scarcity conditions in many parts of the country. Ground water crisis is not the result of natural factors but in majority has been caused by human actions. During the past two decades, the water levels in several parts of the country have been falling rapidly due to increase in extraction of the resource coupled with reduction in natural recharge. The number of wells drilled for irrigation of both food and cash crops have rapidly and indiscriminately grown in southern states and states in western parts of the country.

India's rising population and changing lifestyles have also increased the water required in domestic sector. Water needs for the industrial sector is also showing an overall increase in use of ground water resources. Intense competition among users in agriculture, industry and domestic sectors to fulfill their requirements through ground water resources has significantly lowered the water table. The quality of ground water is also getting severely affected because of widespread pollution, limiting the availability of fresh water. Besides, discharge of untreated wastewater through bores and leachate from unscientific disposal of solid wastes also contaminates ground water, thereby deteriorating the quality of fresh water resources.

Uncontrolled use of the bore well technology has led to the extraction of ground water at such a high rate that natural recharge to aquifer is not sufficient to replenish it. There is also lack of adequate attention to water conservation, efficiency in water use, water re-use and artificial recharge of ground water. Present scenario of ground water development cannot be left as it is.

Ground Water Development

There is phenomenal growth in utilization and development of ground water due to its significant contribution in fulfilling the demands of fresh water by various sectoral users in the country. More than 85 % of water supplies for domestic use in rural areas, 50% of water supply for urban and industrial areas and more than 50% of irrigation water requirement are being catered through ground water resources. During prolonged drought periods, ground water is generally the main source of water supply. National Commission for Integrated Water Resources Development, 1999 has estimated that 843 BCM of water will be required by 2025 from all sources (High demand scenario) and out of this, about 298 BCM (35.3%) of annual water requirement is to be met from ground water sources in the country.

The ground water availability in the Indian sub-continent is highly complex due to diversified geological formations, complexity in tectonic framework, climatological dissimilarities and changing hydro-chemical environments. Ground water development in different areas of the country is not uniform. There is intensive development of ground water in certain areas, which has resulted in over –

*Member, Central Ground Water Board.

exploitation of the ground water resources and led to declining trend in levels of ground water. As per the latest assessment of ground water resources carried out jointly by the Central Ground Water Board and the concerned States, out of 5723 assessment units (Blocks/ Mandals/Talukas) in the country, 839 units in various States have been categorized as 'Over-exploited' i.e. the annual ground water extraction exceeds the annual replenishable resource and significant decline in long term ground water levels has been observed either in pre- monsoon or post-monsoon or both. In addition, 226 units are 'Critical' i.e. the stage of ground water development is above 90 % and within 100% of annual replenishable resource and significant decline is observed in trend of long term water levels in both pre-monsoon and post-monsoon periods. The state-wise status of over-exploited and critical areas are given in Table 1.

TABLE -1 Categorization of Blocks/ Mandals/ Talukas in India (Assessment year -2004)

Sl.No.	**States / Union Territories**	**Total No. of Assessed Units**	**Over-exploited**		**Critical**	
			Nos.	**%**	**Nos.**	**%**
	States					
1	Andhra Pradesh	1231	219	18	77	6
2	Arunachal Pradesh	13	0	0	0	0
3	Assam	23	0	0	0	0
4	Bihar	515	0	0	0	0
5	Chattisgarh	146	0	0	0	0
6	Delhi	9	7	78	0	0
7	Goa	11	0	0	0	0
8	Gujarat	223	31	14	12	5
9	Haryana	113	55	49	11	10
10	Himachal Pradesh	5	0	0	0	0
11	Jammu & Kashmir	8	0	0	0	0
12	Jharkhand	208	0	0	0	0
13	Karnataka	175	65	37	3	2
14	Kerala	151	5	3	15	10
15	Madhya Pradesh	312	24	8	5	2
16	Maharashtra	318	7	2	1	0
17	Manipur	7	0	0	0	0
18	Meghalaya	7	0	0	0	0
19	Mizoram	22	0	0	0	0
20	Nagaland	7	0	0	0	0
21	Orissa	314	0	0	0	0
22	Punjab	137	103	75	5	4
23	Rajasthan	237	140	59	50	21
24	Sikkim	1	0	0	0	0
25	Tamil Nadu	385	142	37	33	9
26	Tripura	38	0	0	0	0
27	Uttar Pradesh	803	37	5	13	2
28	Uttaranchal	17	2	12	0	0
29	West Bengal	269	0	0	1	0
	Total States	**5705**	**837**		**226**	
	Union Territories					
1	Andaman & Nicobar	1	0	0	0	0
2	Chandigarh	1	0	0	0	0
3	Dadra & Nagar	1	0	0	0	0
4	Daman & Diu	2	1	50	0	0
5	Lakshadweep	9	0	0	0	0
6	Pondicherry	4	1	25	0	0
	Total UTs	**18**	**2**		**0**	
	Grand Total	**5723**	**839**		**226**	

Note

Blocks- Bihar, Chhattisgarh, Haryana, Jharkhand, Kerala, Madhya Pradesh, Manipur, Mizoram, Orissa, Punjab, Rajasthan, Tamil Nadu, Tripura, Uttar Pradesh, Uttaranchal , West Bengal

Mandals (command/ non-command) - Andhra Pradesh Talukas - Goa, Gujarat, Karnataka, Maharashtra

Districts - Arunachal Pradesh, Assam, Delhi, Meghalaya, Nagaland

Districts (Valley) - Himachal Pradesh, Jammu & Kashmir

State – Sikkim Islands – Lakshadweep

UT - Andaman & Nicobar, Chandigarh, Dadra & Nagar Haveli, Daman & Diu, Pondicherry

CRITERIA FOR CATEGORIZATION

Over-Exploited blocks :Stage of Ground water development - >100%, Significant decline in long term water level trend in either pre-monsoon or post-monsoon period or both

Critical blocks : Stage of Ground Water Development - >90% and <=100%, Significant decline in long term water level trend in both pre-monsoon and post-monsoon period

Regulation of Ground Water Development

Water is a State subject and water resource management is the overall responsibility of State Governments as per the Constitutional provisions in the country. Ground water resources made a significant contribution during Green Revolution for making country self sufficient in food. This resulted in phenomenal increase in number of abstraction structures leading to over-exploitation of resource in some pockets in the country. A limited control existed on over exploitation of ground water through indirect measures, like stipulation of spacing criteria between ground water structures by financial institutions (like NABARD), technical clearances of ground water development schemes by Ground Water departments, denial of power connections for pump sets etc by the concerned states. In order to enable the States to frame and enact ground water legislation for ground water governance on scientific consideration, a model bill was circulated by Government of India in 1970 to all States. The provisions of Model bill included constitution of State Ground Water Authority and the modalities for regulation of ground water resources.

Constitution of Central Ground Water Authority

A Public Interest Litigation was filed before the The Hon'ble Supreme Court of India in 1996 in reference to alarming decline of ground water levels due to over-exploitation of ground water resources in the country. Subsequently, under the directive of Hon'ble Supreme Court, the Central Ground Water Board was constituted as an Authority under Section 3 of the Environment (Protection) Act, 1986 vide notification no. S.O. 38(E) dated 14.1.97 for the purposes of regulation and control of ground water development and management in the country.

The Authority has been conferred with the power (i) To exercise of powers under section 5 of the Environment (Protection) Act, 1986 for issuing directions and taking such measures in respect of all the matters referred to in sub-section(2)of section 3 of the said Act (ii) To resort to penal provisions contained in sections 15 to 21 of the said Act. (iii) To regulate and control, management and development of ground water in the country and to issue necessary regulatory directions for the purpose. (iv)

Exercise of powers under section 4 of the Environment (Protection) Act, 1986 for the appointment of officers.

Notification of Ground Water Overexploited Areas

The Central Ground Water Authority has notified 43 critical / overexploited areas in parts of NCT Delhi, Haryana, Punjab, Andhra Pradesh, Rajasthan, MP, Gujarat, West Bengal, Uttar Pradesh and Diu for control and regulation of development of ground water resources (Table2). For enforcement of the regulatory measures in these areas, concerned Deputy Commissioners/ District Magistrates have been directed under Section 5 of Environment (Protection) Act, 1986 to regulate ground water development in notified areas. In these notified areas, installation of new ground water abstraction structures is not permitted without specific prior approval of the Authority. For more effective regulation of ground water development and management, Advisory Committees under the Chairmanship of District Collectors/ Deputy Commissioners with members drawn from various organizations have been constituted. Such Committees will render advice to the District Collectors/ Deputy Commissioners in matters pertaining to regulation of ground water development and management. Advisory Committees for notified areas of Diu, Ghaziabad, Gurgaon, Jothwara, Jhunjhunu, Mundwa, Chirawa, Buhana and Pushkar Valley have already been constituted.

The 65 nos. of over exploited areas showing very steep declining trend in ground water levels in various states are notified for registration of existing ground water abstraction structures. Based on the data thus generated, action for notifying these areas for regulation of ground water abstraction has been initiated. List of these critical areas, as per the ground water estimation (2004) has been circulated to the State Pollution Control Boards and Ministry of Environment & Forests to refer proposals of new industries/ projects falling in such areas to CGWA for obtaining no objection / permission. The Authority has also issued directions to Group Housing Societies, Institutes, Hotels, Industries, Farm Houses, etc. in the notified areas of Delhi, Faridabad, Gurgaon and Ghaziabad and other areas of NCT Delhi where ground water table is below 8 metres from ground surface, to adopt roof top rain water harvesting system. In order to develop a database on drilling activities being carried out, in the country, for regulatory measures, drilling agencies constructing tube wells / bore wells for extraction of ground water are being registered. Such data base not only provides information on current pace of ground water development scenario but also decipher micro level site specific information on ground water availability and technology advancement for development of the same. As regulatory measure, the drilling agencies have been prohibited to take up the work of construction of water wells in the notified areas, without prior approval of the Authority. They are also required to submit the details of drilling undertaken by them within one month of construction of water wells.

Withdrawal of ground water by industries/ projects in 839 Over-exploited and 226 Critical Assessment Units is also being regulated in the country. Permission for drilling tube wells is being granted only to the Government agencies responsible for drinking water supply. Ministry of Environment and Forests has also constituted various technical Expert Committees for environmental appraisal of various categories of developmental projects, under the provisions of Environmental Impact Assessment Notification and based on the recommendation of such committees, environmental clearances are accorded by the Ministry.

Table 2 – Areas Notified for Regulation of Ground Water Development by Central Ground Water Authority

S. No.	State	District	Block/ Mandal
1	Andhra Pradesh	Chittoor	Tirupathi (Rural)
2	Andhra Pradesh	Mahboobnagar	Midjil Mandal
3	Andhra Pradesh	Cuddapah	Vempalli
4	NCT, Delhi	South	-
5	NCT, Delhi	South West	-
6	NCT, Delhi	-	Yamuna Flood Plain Area
7	Diu	Diu	Diu
8	Gujarat	Gandhinagar	Gandhinagar taluka (below 200 mbgl)
9	Haryana	Faridabad	Municipal Corporation of Faridabad & Ballabgarh
	Haryana	Gurgaon	Gurgaon
11	Haryana	Karnal	Karnal
12	Haryana	Kurukshetra	Shahbad
13	Haryana	Mahendragarh	Nangal Chowdhary
14	Haryana	Mahendragarh	Narnaul
15	Haryana	Panipat	Samalkha
16	Haryana	Rewari	Khol
17	Madhya Pradesh	Dhar	Dhar
18	Madhya Pradesh	Dhar	Manawar
19	Madhya Pradesh	Indore	Indore Municipal Corporation
20	Madhya Pradesh	Mandsaur	Mandsaur
21	Madhya Pradesh	Mandsaur	Sitamau
22	Madhya Pradesh	Neemuch	Neemuch
23	Madhya Pradesh	Ratlam	Jaora
24	Punjab	Ludhiana	Ludhiana City
25	Punjab	Moga	Moga I
26	Punjab	Moga	Moga II
27	Punjab	Sangrur	Ahmedgarh
28	Punjab	Sangrur	Mahal Kalan
29	Punjab	Sangrur	Sangrur
30	Rajasthan	Ajmer	Pushkar Valley
31	Rajasthan	Alwar	Behror
32	Rajasthan	Jaipur	Jhotwara
33	Rajasthan	Jalore	Bhinmal
34	Rajasthan	Jalore	Jalore
35	Rajasthan	Jalore	Raniwara
36	Rajasthan	Jhunjhunu	Buhana
37	Rajasthan	Jhunjhunu	Chirawa
38	Rajasthan	Jhunjhunu	Surajgarh
39	Rajasthan	Nagaur	Mundwa
40	Rajasthan	Sikar	Dhod
41	Rajasthan	Sikar	Sri Madhopur
42	Uttar Pradesh	Ghaziabad	Municipal Corporation of Ghaziabad
43	West Bengal	East Medinipur	Haldia Industrial Complex (Aquifer below 120 mbgl)

Model Bill to Regulate Development and Management of Ground Water

To enable the States to enact Ground Water Legislation, a Model Bill to Regulate and Control Development of Ground Water has been circulated by the Ministry of Water Resources to all the States/UTs in 1970 and recirculated in 1992 and 1996 for adoption. 'Water' being a State subject, legislation for regulation and management of ground water is to be enacted by the States. Andhra Pradesh, Goa, Tamil Nadu, Kerala, West Bengal, Himachal Pradesh and Union Territories of Lakshadweep and Pondicherry have enacted and implemented ground water legislation.

In the revised Model Bill circulated in 2005, a new chapter on Rainwater Harvesting for Recharge has been introduced, which provides for :

a) Identification of recharge worthy areas, issuance of necessary guidelines for adoption of rain water harvesting for ground water recharge in these areas and issuance of direction by the Authority to the concerned Department to include rainwater harvesting in all development schemes falling under notified areas.
b) Imposition of stipulated conditions by the Municipal Corporation or any other local Authority for providing roof top rainwater harvesting structures in the building plan in an area of 100 Sq m or more, while according approval for construction.
c) Promotion of rainwater harvesting and artificial recharge by the Authority through Mass Awareness and Training Programmes.

Adoption of Rainwater Harvesting and Recharge

States like NCT Delhi, Tamil Nadu, A.P., Gujarat, Kerala, Uttar Pradesh and Municipal Corporation of Jaipur, Ludhiana, Jalandhar, Haryana, Maharshtra, Jharkhand, Himachal Pradesh and Karnataka have initiated action for making roof top rainwater harvesting mandatory by modifying building bye-laws. The action initiated by various State Government Agencies is indicated in Table 3.

The Central Ground Water Board has also prepared a manual and a guide on Artificial Recharge to Ground Water for providing guidelines on investigation techniques for selection of sites, planning and design of artificial recharge structures, economic evaluation and monitoring of recharge facility. Such information is also available in the official website of Central Ground Water Board (www.cgwb.gov.in) It is of immense use to States/ U.Ts. in planning and implementation of recharge schemes for augmentation of ground water in various parts of the country. Booklets on rain water harvesting and recharge have also been released by the State Government and NGOs for the knowledge and awareness of public.

Mass Awareness

Other than legislation and regulation of ground water over exploitation, society itself plays a very important role in conserving the quantity and quality of the resources. During the last decade, there has been a rising awareness among the common people on the need for conservation and development of ground water.

Table 3: Action initiated by various State Governments on provision of Rain Water Harvesting in Model Ground Water Bill

S.No.	Central/State Govt. Agencies	Action initiated
1.	NCT. Delhi	Modified Building Bye-laws, 1983 to incorporate mandatory provision of roof top rain water harvesting in new building on plots of 100 sq.m. through storage of rain water runoff to recharge underground aquifer in NCT, Delhi.
2.	Tamil Nadu	Roof top rainwater harvesting mandatory in all Corporations and Municipalities.
3.	Andhra Pradesh	Enacted 'Andhra Pradesh Water, Land and Tree Act, 2002' with appropriate provision making it mandatory for new buildings on plots of 200 sq.m. or above.
4.	Gujarat	In metropolitan areas no approval on new building plan without corresponding rainwater harvesting structure.
5.	Kerala	RWH mandatory as per Kerala Municipality Building (Amendment) Rules, 2004 for all new buildings.
6.	Uttar Pradesh	U.P.Housing Board has made roof top rain water harvesting mandatory in new buildings of more than 300 Sq. m area in U.P.
7.	Jaipur Municipal Corporation, Govt of Rajasthan	Roof Top rain water harvesting mandatory in State owned buildings of plot size more than 500 Sq m and for Jaipur Metropolitan area buildings of plot size more than 500 Sq m
8.	Municipal Corporation of Ludhiana and Improvement Trust, Jalandhar, Punjab	Bye-laws have been framed by Municipal Corporation of Ludhiana and to make rain water harvesting mandatory in new buildings
9.	Haryana	Haryana Municipal Building Bye-laws 1982 amended to incorporate the provision of compulsory RWH.
10.	Maharashtra	Maharashtra Government is promoting roof top rainwater harvesting under the "Shivkalin Pani Sthawan Yojana". It provides that all houses should have provision for rainwater harvesting without which house construction plan should not be sanctioned. Bombay Municipal Corporation and Pimpri - Chinchwad Municipal Corporation. Rain Water Harvesting has been made mandatory by enacting building bye-laws.
11.	Jharkhand	Chief Minister has directed to amend the law appropriately for making roof top rain harvesting mandatory in urban areas of Jharkhand State and Rain Water Harvesting in Bye-laws by Ranchi Regional Development Authority
12.	Himachal Pradesh	RWH from the roof tops made mandatory for all buildings which come up in urban areas of the State in future. All commercial/institutional buildings existing or proposed for construction in future and having plinth area of more than 1000 Sqm. located in the State.
13.	Karnataka	Karnataka Government has initiated action to amend building bye-laws in major cities having population of more than 20 lakh to make rain water harvesting mandatory.

It is well recognized that water use need to be integrated effectively with water regeneration. No single action whether community based, legislation of traditional water harvesting systems will in itself alleviate the crisis in the country. The effective solution to ground water crisis would be to integrate conservation and development activities – from water extraction to water management – at the local level, making communities aware and involving them fully is therefore critical for success.

Steps in this regard are being taken all over the country by the Central / State Government agencies / NGOs, VOs, welfare organizations, educational institutes, industries and individuals to promote rainwater harvesting and recharge through mass awareness programmes and trainings to develop resource persons for designing rainwater harvesting structures to augment ground water in different terrains and diverse hydrogeological conditions. Water conservation campaigns involving women, children, farmers etc to create awareness about importance of the resource and its conservation are being arranged. Publicity through print media, meghdoot post cards, slogans on mail vans and letter boxes, telecasting of spots on Doordharshan, broadcasting messages on AIR / AIR FM etc are also done frequently by the Central and State Governments.

Training in Rain Water Harvesting

Implementation of rainwater harvesting and recharge to ground water aquifers, though being a simple process, but it needs some technical knowledge. To make the program of recharge successful, it is necessary that techniques of rainwater harvesting and recharge are implemented using scientific knowledge and technical skills.

The Central Ground Water Authority has conducted 245 training programmes to generate resource persons as a measure of capacity building for designing rainwater harvesting structures to augment ground water in different terrains and diverse hydrogeological conditions. Films on Rain water harvesting in urban areas, rainwater harvesting in rural areas, ground water pollution etc were also produced and are being used for awareness on conservation of ground water. Technical guidance and design have been provided for rainwater harvesting structures for more than 2500 sites in various parts of the country.

Sum Up

Ground Water is considered as most reliable resource amongst water users in the country. Measures for creating awareness among people for efficient use of water, proper demand management by the supply agencies and implementation of rain water harvesting and recharge techniques are necessary for ensuring long term availability of the resource. Education and publicity campaigns on water can play an important role in making public conscious about efficient use of water and its conservation. However, where there are alarming situations of declining water levels, ingress of saline water into fresh water aquifers and destruction of aquifers, regulation on withdrawal from aquifers is also necessary. Policies towards various heavy consumption user sectors need to be formulated taking in to consideration realistic view of ground water resources.

Theme: Role of different Panchayati Raj Institutes, Agricultural Universities, Rural Institutes, Women Institutes and Private Sector in Ground Water Conservation and Sustainable and Equitable Use

ROLE OF PANCHAYAT WOMEN LEADERS IN GROUND WATER CONSERVATION AND SUSTAINABLE AND EQUITABLE USE

Rita Sarin*

We are all aware that wars will be fought for water and not for land in future. With six billion people inhabiting the earth going further up every day and with Green House emissions melting the glaciers across the world, the sudden upsurge of water in the world is going to be very short-lived. Moreover, the present swell in the rivers is flowing into the seas and the oceans and not benefiting anyone even in the short term.

I am aware that there are many arguments and debates over water conservation. It is a telling example that Cherrapunji – one of the wettest places not just in India but in the world faces acute water shortages in winter – there is not enough potable water for drinking and the people have to walk for miles to get water for their daily needs!

Who would know this shortage better than women who struggle to provide fresh drinking water to their families along with catering to basic hygienic needs of their communities for bathing and cleaning? Shortage of drinking water is something that rural women are well aware of. In every village across the country, rural women walk miles to fetch drinking water for their families every day. As it is, it is mainly women who have the daily chore of storing, carrying and gathering water – to wash clothes, dishes, cook food, etc. Its shortage, scarcity and unavailability have the greatest impact on their family as well as lives. Long years of drought and water shortages in one form or the other have affected every village woman's life in India.

For a very long time rural women have had no access to plans and processes that allowed their voices in creating and covering the basic needs like water, health and education for their families and communities. It is here that the 73rd Amendment to the Constitution makes sense and all the difference. The amendment has given more than one million elected women *Panchayat* representatives a platform to address issues related to their own welfare. These women *Panchayat* leaders have taken on the mantle of leadership to address issues of food security, water, education, health and nutrition. While most governments are in the process of devolving the 29 subjects, the subject of water has been devolved in all *Panchayats*. And almost all elected women *Panchayat* Leaders are addressing issues of water – its availability, conservation and sustainable use.

In the past ten years of elected women as panchayat leaders, we already have hundreds of instances where women have redefined the development agenda by prioritizing the needs and their fulfillment.

We have pioneering work done by elected women leaders like Mrs. Vishlesha Kolge, who was elected for the first time on a reserved seat (for women) from Palpene Gram panchayat from Guhagar block, Dist. Ratnagiri in Maharashtra. She started to interact with the community and gradually began asserting herself, going to the block office to get information on various schemes available.

Though she was aware of the drought situation in Ratnagiri district and the low ground water table, it was only during her interaction with the village community that the severeness of the situation was highlighted. Her first step was to purify the existing water sources in the *Panchayats*. Ponds were desilted, wells were cleaned and drains covered. During her regime she accessed tap-water supply schemes from

*Country Director, Hunger Project

the government, constructed water pool (Tali) and small ponds of water (Durah). Water conservation schemes have also been implemented successfully. Her effective planning and monitoring has produced such high quality of work that her *Panchayat* gained recognition (ranked 2nd in district) by Zilla Parishad.

Though women leaders are initially more concerned about bringing clean drinking water supplies to the villages, the concept of conserving and making sustainable use of water is not new to them. Traditional water harvesting methods such as *tankas, zings, ahars* and *johads* are methods familiar to the rural women. Bangalore was once a city of tanka's – most of which today have either dried up, are silted over or filled up due to growing urbanization. With little or no support from the administration, the populace - both in urban and rural India - have had to abandon these traditional rainwater harvesting structures.

These methods of water harvesting need to be either revived or re- introduced. The women leaders in the *Panchayats* are taking proactive measures to revive existing water bodies. They are implementing water conservation as well as rainwater harvesting programs. Elected women representatives are keenly aware of the water related problems of the local communities in which they live and work. Belonging to agricultural communities, they are aware of impact of water scarcity on their working as well as personal lives. Bharti Devi, Pradhan of Titotiya *Panchayat* in the hilly district of Pauri, Uttaranchal, focused her work again on establishing a pipeline for providing water supply in the villages. She reconstructed the existing channels of water supply and prepared anicuts for preserving the rainwater for agriculture purpose.

Jesu Mary is the President of the Michael Pattinam *Panchayat* in the Mudukalathur block in Ramnad District of Tamil Nadu. Having held office for the last 9 years, Jesu Mary has ensured that all 250 households in her *Panchayat* have a toilet and a rain-water harvesting facility. Her efforts in rainwater harvesting led her to USA where she was invited to a rainwater harvesting conference.

Not content with installing rainwater facilities at the individual household level, she has now installed a rainwater harvesting system at the village tank as well. Where women in her village had to either walk three kilometers to fetch water or resort to buying water, they now have enough water for all their needs thanks to Jesu Mary. From the money saved, Jesu Mary has provided two sets of trash cans for every home so that they can segregate the recyclable and non bio degradable waste.

The elected women representatives are committed to making a difference to the lives of *all* in their communities. Jyothimani is a member of the *Panchayat* Union Council of Gudalur West *Panchayat* in Karur District of Tamil Nadu. She was elected at the age of 21 years and her first priority was to provide on *equal terms* drinking water to a Dalit hamlet in her constituency. She then slowly ensured that all villages in her jurisdiction have 100% water supply. As there was a shortage of water in the area, Jyothimani implemented a rainwater harvesting programme and today seventy-five percent of the water requirements are met with the help of the rainwater harvesting programme.

These women leaders are not isolated cases. In most *Panchayats*, one would find the elected women playing active role in water conservation and harvesting. In the Tsunami affected villages the women are playing a critical role in desalinating and restoring water bodies through alternate cropping methods. In the villages of Rajasthan, the women are mobilizing the community to construct check dams to see them through the drought years. These women who have been victims of water shortage for so many long years are exercising their political leadership to deal with the administration and also to create awareness within their own communities.

The biggest challenge facing the women *Panchayat* leaders today is the lack of planning at the grassroots. Various government and non government organizations have set up parallel water committees in the villages. There are numerous studies and reports on initiatives taken by civil society groups. These groups have, all over the country, separately worked on different aspects of water resource management. These committees have not aligned themselves to the *Panchayats* and work in isolation. The *Gramsabha* is left out in the process though each citizen is a water user. The district administration too plans schemes with a top down approach, in the process ignoring local wisdom and knowledge. What is needed is a concerted *institutionalized* grassroots approach to sustainable water resource management. Local communities need to be consulted when planning for water conservation and its sustainable use. The ownership needs to lie with the community and not be imposed top down if it is to be implemented efficiently.

There is a need to re-think on our public policy framework with regard to sustainable water resource management at the village level.

The urgent need is for de-centralization and transformation of the highly inefficient and ineffective water management system. There is a need to include community level stakeholders and *Panchayat* office bearers in the planning and implementation of all works regarding land-use, revival of or even introduction of methods of water resource management, irrigation and sanitation.

An effective way to implement a broad sustainable water resource conservation and rainwater harvest strategy is to have elected Women representatives actively supported with effective policy and administrative changes designed specifically to revive traditional systems of water harvesting and spread awareness of water conservation. However, this action must be tailored to fit each individual communities needs. There is still time for the government to broadly outline a strategy to help alleviate and perhaps forestall the upcoming crisis. Individual EWR's (elected women representative) of *Panchayati* Raj Institutions have amply demonstrated their competence and the time has come that these leadership efforts need to be supported with policy initiatives.

There are 1.2 million Elected Women Representatives in the country – this is not a number which can be overlooked – whose energy, competence, efficiency and commitment can be harnessed to resolve the water crises threatening the country in the coming years.

ROLE OF *PANCHAYATS* IN GROUND WATER MANAGEMENT

G.Palanithurai*

Introduction

Conservation of natural resources was effectively done by the communities with the advice of local experts and by following community laws. It is evident that management of water resources was one of the responsibilities of the communities at the grassroots level ever since communities were recognized as responsible institutions for governance. There are arguments that community organizations were quite effective in natural resource management and hence all over the world a search is on for reviving and reinventing the community organizations to take over such age old responsibilities of managing natural resources. It is also equally true that many of these community-based institutions have excluded many marginalized groups from the orbit of managing the natural resources. After the establishment of Nation-State system, the state assumed responsibilities of the traditional organizations. Yet, the government institutions neither enriched nor protected effectively the natural resources and hence they turned again toward community organizations. Over a period of time, the modern State system, by its ruling character, has reduced the people to abject beneficiaries and petitioners. Despite the all-pervasive presence of government, people strongly believe only in the community system and have retained the management of water bodies and temples with them. Water bodies are retained with the community as their livelihood depends on them in the same way temples are retained with the communities as they are the pride of the communities. Tanks and temples were sacred to the community. Over a period of time the political institutions, by their activities, started breaking the local communities and communities lost their power over the natural resources and other community assets. As a result, community assets have been neglected, abused and encroached upon.

To bring back the people to the process of governance and evolve a plan for the development of communities, a new institutional mechanism has been created through the Constitution. The 73rd Amendment to the Constitution of India has provided enough scope for the people to evolve a micro plan for each and every *Gram Panchayat* by which natural resources can be managed, infrastructure facilities created, and the created infrastructure facilities be utilized properly and productively. The plan should aim at achieving economic development and social justice.

In the 73rd Amendment there is a provision in the 11th Schedule for the *Panchayats* to deal with maintenance of community assets. A variety of activities related to water harvesting, water conservation and regulation of use of water can be planned and implemented by the *Panchayati* Raj Institutions. Out of the 29 items listed in the 11th Schedule of the Indian Constitution, at least eight items are closely related to the use of water. They include minor irrigation, watershed development, water management, land improvement, soil conservation, minor forest, social forestry, drinking water, agriculture and fisheries.

Many of the state acts have given varied vital responsibilities related to conservation and management of water. In Tamil Nadu, maintenance of minor irrigation works like irrigation tanks, management of common lands and unreserved forests are entrusted to *Panchayats*. Most of the programmes of State and Central Governments related to water and land are implemented by the *Panchayats*. Programmes like the Rural Employment Guarantee Scheme have opened tremendous opportunities for *Panchayats* to work in the area of water harvesting and conservation.

*Professor, Department of Political Science and Development Administration Gandhigram Rural Institute - Deemed University Gandhigram - 624 302, Tamil Nadu.

They have also demonstrated that the available ground water can be used economically and distributed equitably. *Panchayats* have demonstrated that they can create a water culture at the grassroots. Many *Panchayats* have successfully improved ground water through rainwater harvesting, construction of check dams, percolation ponds, desilting of water bodies and maintenance of supply channels. Ground water is also a common property like irrigation tanks. It is the responsibility of the state to regulate the use of ground water. But due to various reasons, the state is not in a position to effectively implement regulatory measures to ensure economic and scientific use of ground water. Many of the acts and rules regarding regulation of use of ground water are hardly implemented. Water mining has become an industry and it is going on in the nooks and corners of the rural area and the state has very limited information on these activities. Due to urbanization, commercialization of agriculture, collapse of traditional institutions and land reform policies, the common men are under threat and water bodies all over the country are under stress. Encroachment of water bodies is politically encouraged. A new water market has emerged and water is converted into a commodity. Free distribution of electricity for agriculture and commercialization of agriculture encouraged large scale use of ground water. Water lords have emerged in rural areas who control use of ground water. Over exploitation of ground water has resulted in the exclusion of marginal farmers from irrigation. Large scale rural indebtedness and suicides have resulted from over exploitation of ground water.

Panchayats have demonstrated that they could emerge as the guardians and custodians of water. In many parts of Tamil Nadu, Village *Panchayats* have emerged as models for conservation of water and development of ground water. A variety of community-based innovative strategies have been identified and used by them. As per the Tamil Nadu *Panchayati* Raj System, the following activities have been entrusted to the *Panchayats*.

Minor Irrigation

1. Village *Panchayats* can assist the *Panchayat* Unions to identify the tanks with ayacut area of less than 100 acres and for the collection of information on water spread area, water holding capacity and period of storage to plan and execute necessary works.
2. Taking appropriate action for desilting of tanks with an ayacut of less than 100 acres during summer season for increasing the water storage capacity of the tanks.
3. The Village *Panchayats* may avail such benefits for reconstruction of supply channels of tanks with an ayacut of less than 100 acres and sinking of deep bore wells.
4. Assist in the identification of beneficiaries under Western Ghat Development Programme.

Water Management

1. The respective Village *Panchayats* can initiate action to collect details regarding the water table of their area from the Geologist and take suitable action.
2. The Village *Panchayats* may take steps to search for the possibilities of sinking bore wells for improving irrigation facilities in cultivable lands.
3. The message of keeping adequate spacing between two open wells as per the opinion of the Geologist may be spread among the public.

Watershed Development

1. The Village *Panchayats* can assist in the compilation of details on land records, information on cultivable lands, pastures, wastelands, water harvesting structures, tanks bunds and other *Panchayat* lands and community assets, detect encroachments and evict such encroachments.
2. Taking actions to implement schemes under Watershed Development Programme should be in the domain of Village *Panchayats*. In order to increase the production and proper usage of public land and other assets, Village *Panchayats* may supervise and take necessary action in coordination with various departments for conservation of natural resources and protecting the ecology and environment.
3. The Village *Panchayats* can prepare plans and implement the Watershed Development Programme in their areas. They can also identity the type of trees and plants which are suitable to the soil types.
4. Village *Panchayats* can assist in the identification of beneficiaries under the Watershed Development Programme.

From the time of inception of the New *Panchayati* Raj System, various activities under the subject ‘Minor Irrigation’ have been implemented by the Village *Panchayats* from the allocation of state and central scheme funds. The Village *Panchayat* leaders, in course of time, after building their capacity to manage the affairs of the *Panchayat*, strengthened their vision in respect of common property resources, its protection and promotion and its better utilization. Especially the activities under ground water management are now slowly picking up as schemes like JRY, NREGA and DPAP very particularly demand the Village *Panchayats* to plan and execute the activities pertaining to augmenting ground water sources.

There are a large number of *Gram Panchayat* leaders who are sensitive to this issue and they have taken keen interest in mobilizing the people and have carried out a lot of activities in their respective *Panchayats*. Many of them are women and dalits. They are committed carry out these activities by using the limited powers devolved to them. They have achieved this in spite of a volley of problems and through constant struggle. Yet, after completing the activities and seeing the implications, people have started supporting the *Panchayat* leaders. A few cases selected from Tamil Nadu are presented below

Village *Panchayats*

Ms.Jesumary, President, Michael Pattinam *Panchayat*, Ramnad District

> Michael Pattinam is a very dry area. The people depend on rain to undertake farm activities. Only a few families have wells. She explained to the people that the waterways should be cleaned before the rain and desilting of tanks has to be done. She also told them that desilting of tanks would help not only agricultural activities, but also their cattle. She convened the *Gram Sabha* meeting and explained to them about the conditions. The villagers worked overnight and they cleaned the waterways and strengthened the check dams. It was a pleasant shock to the other *Panchayat* Presidents and officials including the District Collector. Everyone realized the potential of the community, and it was a breakthrough in her work, which has elevated her image among the people. She is known throughout the state for her innovative techniques of rainwater harvesting. She took pains to convince the

people. She created a pucca rain water structure in all the streets of the village. She has been cited in the letter written by the then Chief Minister J.Jayalalitha to *Panchayat* leaders. She is a pioneer in rain water harvesting. She was invited to Washington by the World Bank. She got several awards. Further she constructed several check dams in her *Panchayat* area despite opposition from other villages.

Ms.Rani Sathappan, President, K.Rayavaram *Panchayat*

In K.Rayavaram *Gram Panchayat* of Pudukkottai District, there are three ponds and four tanks. Of these four tanks, two belong to the Public Works Department and the remaining two are under the control of the *Panchayat* Union. There were encroachments in all the ponds and tanks. Ms.Rani Sathappan was aware that desilting of all these ponds and tanks will help in improving the water table in the area. So she approached the District Collector for permission. As they were PWD tanks, the District Collector directed her to approach the PWD officials and also he recommended to the PWD officials to do the needful. In spite of the Collector's advice, the PWD officials were reluctant to issue a 'No Objection Certificate'. Yet through prolonged persuasion she got the certificate. She evicted the encroachers, desilted the tanks, strengthened the tank bunds and planted trees on the bunds to strengthen the same. Similarly in the ponds also she took efforts to desilt the beds and strengthen the bunds with the help of the community to harvest rain water, enabling improvement in the water table.

Ms.Ponnikailasam, President of Anaikuppam *Panchayat*, Thiruvarur District

Agriculture is the major source of livelihood to the people settled on the river side of this *Panchayat*. They also depend on the Cauvery river with its mini tributaries and its channels for water. But a major portion of the channels were encroached upon for various purposes like agriculture and mining, resulting in poor inflow of water. So the *Panchayat* President, Ponni Kailasam, decided to evict all the encroachers and to desilt the channels. So she convened a special *Gram Sabha* for this purpose. After a great struggle she collected all the details about the areas encroached upon from the records. There was a threat to her life from a gang for this reason. But she didn't tire. She continued her struggle and evicted the encroachers, desilted the channels, planted palmyrah trees on the banks to strengthen them. As a result there is free flow of river water in the channels and also it enables all the ponds and tanks to be filled with water.

Keeranur *Gram Panchayat* Experience of Management of Common Resources – The Water Bodies – Dindigul District

The village Keeranur and other hamlets are located at the foothills of the Malleswarar Hill. There are twenty seven ponds/tanks under the jurisdiction of the Village *Panchayat*. As agriculture is the major occupation and the majority of the lands are rainfed, protection and maintenance of all water bodies is very important. Hence the Village *Panchayat* administration decided to give priority to improving the ponds/tanks, canals and streams so that the ground water level will improve. Nattuthurai, President of the *Gram Panchayat*, acknowledged the training given by the Rajiv Gandhi Chair for *Panchayati* Raj Studies, Gandhigram Rural Institute in sensitizing the *Panchayat* leaders on the significance of scientific management of the village commons. Hence it was decided in the Village *Panchayat* Council not to spend scheme funds on activities other than the watershed activities. Though the expectation of the villagers was generally like provision of sodium vapour lights, CC road, drainage, etc., the reasons for the priority given to the watershed activities was explained to the villagers in the *Gram Sabha* meetings. Further, with the financial assistance of World Vision of India, five watershed works at a cost of about Rs.13.50 lakhs have been successfully carried out, Nattuthurai reported.

Thamaraikulam Village *Panchayat*, Ramnad District

Mr.S.Sivalingam, President of Thamaraikulam *Panchayat* of Ramnad District, stated that tanks and ponds are the essential sources for storage of water and the lifeline of the people. Hence, their maintenance, protection and enrichment will help the people to secure their livelihood. Almost all the twelve tanks have been desilted and deepened. As a result the water level of the sub soil is maintained. Further, all the channels which bring water to these tanks have been cleared and are maintained in such a condition that as and when it rains, even the smallest amount of water will reach the tanks without any wastage.

Jamruth Beevi, Devipattinam *Panchayat*

Ms.Jamruth Beevi, President of Devipatitnam *Panchayat* of Ramnad District has done a major work by identifying a very big water reservoir which was in dilapidated condition. She got information about the Poovodai tank from the elders of that *Panchayat*. She interacted with the elders on the reasons for the declining water table, which used to be at 5 ft. below the ground, going down to 90 feet when there was a water conservation structure. In 1955 there was heavy rain and, as a result, the Poovodai developed a breach and subsequently there was no repairing of the reservoir. All the years' water came to the reservoir and moved away through this breach to the sea.

She started thinking about the Poovodai. When she visited the Poovodai tank she found a lot of encroachments. The dimension of the tank is seven km in length and 100 meters in breadth. When the Minister visited her *Panchayat*, she made a presentation about the condition of the Poovodai and sought assistance. But the Minister, instead of responding to her request, cracked a joke and left the place. The Minister said that the *Panchayat* has to think of what is possible and feasible. The Poovodai is a troublesome project which cannot be done by the *Panchayat*. This speech irritated her. She felt very much and made a declaration that the Poovodai will be made a reservoir to save water for the *Panchayat*. She approached the Collector and explained to him about the Poovodai and got sanction for Rs.25 lakhs under the SGRY scheme. She collected money from the local Jamat and the Saudi Association for this work. They contributed Rs.75,000/- for this work. She removed all the encroachments with the help of the people and the district administration. The Poovodai has now been desilted, deepened and seven small tanks have been created. She considers it a major and memorable work done for the community. She commented that it was possible only because of the District Collector who is sincere and sensible on the issues of the rustic folk.

Conservation and Management of Water

Mr. Ponnusamy, President of Semmipalayam *Panchayat* in Coimbatore District, is not only interested in taking water from the earth and pumping it to the OHT's and from there giving water to individual houses, but also in conserving water through water resource management, natural resource development and conserving soil moisture. According to him, people have to be sensitized on rational utilization of water and water conservation for its sustainability in the *Panchayat* area. He got assistance from the MLA and the MP besides the DPAP (Drought Prone Area Programme). He has constructed four check dams at a cost of Rs.5.50 lakhs. He claims that while implementing the check dam project he distributed 3.7 tons of rice to the poor for their work in the project. He generated 528 man days of employment. Through this work he created a source of recharge for 15 wells and 5 bore wells. All the check dams are very near to the bore wells from which water is lifted to the OHTs. Since he got money from the DPAP, it was imperative that watershed committees be formed through which awareness could be created on the importance of water and the severity of drought. Thus people were made aware and sensitized on issues of water scarcity and ways and means to avoid it.

Yet another work he carried out was the construction of a rain water harvesting system. In his *Panchayat* all the 1656 households have created such a structure following the lead. This work was carried out simultaneously along with the water supply system.

Sitharevu Village *Panchayat*

Sitharevu is a big Village *Panchayat* in Athoor Block of Dindigul District with a population of 20,000. There are 16 hamlets in this Village *Panchayat*. It is a multi-caste and multi-religion Village *Panchayat*. The Village *Panchayat* Council has 15 ward members, 10 men and 5 women. Of the total 15 members two are belong to the SC community.
Agriculture and Animal Husbandry are the main source of livelihood of the villagers. Moreover, a considerable number of landless agricultural labourers have employment opportunities in plantation estates which are located in the nearby Western Ghats area of Panrimalai.
During the year 2005-2006, the DPAP (Drought Prone Area Development Programme) was availed of by the Village *Panchayat* Council. The farmers met together and identified that the maintenance of three inlet channels was the important work apart from land reclamation and construction of retaining wall to regulate the flood water.

The Village *Panchayat* took special efforts to mobilize labourers for this work as usually they preferred employment in plantations. Realizing the significance of maintenance work for the inlet channels to ensure proper flow of rain water into the minor irrigation tanks, the villagers actively participated in the DPAP. At this juncture the NREGA was introduced in this district of Dindigul. Initially the details of the NREGA programmes were not properly explained to the villagers. The President did not give his mind to the implementation of the programme due to his preoccupation with his own affairs. Further it was told that block officials did not give much importance to involving villagers in planning of priorities in the selection of NREGA works. It is learnt that the villagers also did not have much faith in the Village

Panchayat administration. Realizing the benefits of the scheme, the local Congress Party leader who had already oriented the Village *Panchayat* on other public welfare activities, came forward to mobilize the villagers. He, along with a few volunteers and ward members, visited each hamlet and explained the details of the work undertaken and the significance of creating/maintaining the Common Property Resources including water bodies in the Village *Panchayat*.

When the election to the *Panchayati* Raj Institutions was held in the year 2006, this individual contested in the election and won. After he became the President of Sitharevu Village *Panchayat*, the NREGA programme implementation was intensified. He showed due respect to the needs of the villagers of all hamlets and selected works according to their priority. During the year 2006-2007, four projects of desilting and maintenance of minor irrigation tanks have been undertaken. So far 13,000 man days have been generated and about 10 lakh rupees utilized from the allocation of the Rs.15.50 lakhs.

The works undertaken under DPAP were maintenance of inlet channels and under NREGA programme, the desilting of minor irrigation tanks and small ponds. The farmers and common villagers were actively involved in these programmes. As they witnessed the filling of tanks during the South-West Monsoon rainfall (July-August), the farmers told that the ground water resource had improved. The President said that it was only because of both maintenance of channels and desilting of tanks and ponds that the ground water recharge have been augmented. Earlier, there was no perception about all stakeholders in this regard. After the emergence of *Panchayati* Raj Institutions, the villagers have the opportunity to express their needs and issues affecting their livelihood which have been properly projected by the Village *Panchayat* Council. By involving the NREGA the vision of the Village *Panchayat* and the villagers has been realised.

Kameshwaram *Panchayat*

Kameshwaram is one of the Village *Panchayats* in Nagapattinam District, where the NREGP is in progress. In this *Panchayat*, under the NREGA, the President has given preference to ground water related works. There are a number of ponds and tanks in all the hamlets of this *Panchayat*. The President encouraged and sensitized the people on the need for deepening and proper maintenance of these tanks as it will enhance availability of ground water which is useful for agriculture activities as well as to the cattle population. He created awareness among the people about the tasks to be performed by them and the responsibility of the people living in the hamlet to maintain them. This made them work with interest in deepening and desilting the tanks located in their hamlets under the NREGA. This new approach of the President has paved the way for improving the water resources in the village.

NREG Act – Employment Generation – Poothurai Village *Panchayat*

Poothurai is one of the Village *Panchayats* in Vanur Block of Villupuram District in Tamil Nadu. Poothurai is situated on the border of the Union Territory of Puducherry and at the tail end of Villupuram district. Moreover, in Vanur Block there are 65 Village *Panchayats* and for the sake of administrative convenience, it is unofficially divided into two South Vanur and North Vanur. North Vanur is on the border with Puducherry and Poothurai is the tail end village sharing its jurisdiction with Puducherry. Due to its location, far away from the district headquarters, the frequency of higher officials' visit is less, the villagers said.

Poothurai got its name due to the availability of a variety of flower plants in abundance. There is a lake named Poothurai Lake and there are ten tanks located in the main village Poothurai and its hamlets, namely, Kondimedu, Kasi Palayam and Manaveli.

Poothurai is a multi-caste village. The Scheduled Caste (Paraiyar) is the dominant caste. Vanniars are numerically the second dominant group. There are families of Naidu and Pillai castes also. There is communal harmony in Poothurai.

As there is no system of irrigation facilities, the agricultural activities are mainly rainfed based. Now due to failure of monsoon, the farmers prefer casuarina and cashew nut plantations. Paddy cultivation is significantly limited in extent. Due to its proximity to Puducherry, many villagers use to go over to Puducherry for employment. Youths, men and women got employment in industrial and other types of agencies functioning in Puducherry. Animal husbandry is also one of the supplementary income generation activities in Poothurai.

Though there are lakes and tanks in Poothurai, due to lack of interest and community practices in respect of ground water management, the level of the ground water declined. Further due to non allocation of funds for the protection and promotion of the village commons like forest, water, lake and tanks, the optimum utility of these water bodies is not possible. There is no maintenance work carried out for the past two decades, informed the villagers. The implementation of the NREG Act activities since 2006/07 is a boon to the villagers.

When the district officials sensitized the Village *Panchayat* in respect of the implementation and procedures and priorities under NREGA, the Village *Panchayat* Council immediately convened the Gram Sabha meeting and discussed with the community. An estimate of Rs.30 lakhs was projected for carrying out NREG activities like cleaning and maintenance of inlet channels, desilting of Poothurai lake and other 10 water bodies, provision of approach road to burial ground, maintenance work in village roads. After finalizing the project activities under the NREG Act, the Village *Panchayat* gave first priority to ground water management. Out of the first installment of 13 lakh rupees, the Village *Panchayat* spent Rs.10 lakhs towards activities like maintenance of inlet channel of Poothurai Lake. It is a five kilometer distance from the hamlet of Manaveli to Poothurai lake. It has a width of 12 feet to 20 feet. Due to lack of maintenance, in course of time the inlet channel filled up with earth/waste and with growth of wild plants and thorny bushes, its course was disturbed due to encroachment also. Hence in spite of seasonal rains, the water did not reach the lake as it was wasted flowing out at many places.

Presently the inlet channel works like removal of thorny bushes, and other wild plants, desilting of beds, strengthening of bunds, and removal of all encroachments are undertaken. The channel is now getting ready to fill the lake. So far about eleven lakh rupees have been spent on this work.

The work commenced on 25.11.2006 and about 73 days were spent to complete the work. On an average daily 230 workers, mostly women labourers, are engaged in this work. They have received Rs.80/- per day as wages to complete the unit of work assigned by the Village *Panchayat*.

The facilities like provision of protected drinking water to the workers at the site, ensuring arrangement to look after the children of workers, availability of first aid box to attend to any untoward injury and provision of medical care to those who suffer major injury have been properly dealt with by the *Panchayat* administration.

The work is really an endurable one and very much useful to the villagers, the vice-President claimed. He said that more than a decade ago, the government had done the maintenance work in the inlet channel. But the work was not properly carried out due to non involvement of the people. The work under the NREGA is perfectly done. In spite of hardships, the workers gave their energy and mind to the successful implementation, the vice-President added.

The *Panchayat* clerk said that there is a lack of time to do the procedural activities like maintenance of muster roll, obtaining signature for attendance, entry in the job card, distribution of wage amount and obtaining the signature for the receipt of wage amount etc. in addition to the allocation of work at the work site as well as monitoring of the execution of works. At a time an average of 200 to 250 workers turned up for the work. Effective monitoring is a challenge for the 'Makkal Nala Paniyalar' who is also entrusted with the responsibility of implementation of NREG Act activities. The staff shared that many women, in the guise of attending to work, used to while away time; elderly women are not able to contribute to complete the task. They felt that the villagers have not yet realized the significance of the scheme. The villagers have the opinion that since it is the government's money, why should the *Panchayat* insist on measurement? The *Panchayat* staff demanded that there should be a systematic implementation phase wise, area wise and real felt need wise. The salary of the 'Makkal Nala Paniyalar' lower than the worker's and in that case how could he monitor the work of the workers, the clerk shared. Moreover the clerk observed that the spirit and interest among the villagers was seen earlier, is diminishing now as the government officials do not emphasize on the measurement.

The Poothurai *Panchayat* President is a woman. Though she is educated she does not have orientation in public activities. She conducts *Panchayat* Council meetings and organizes Gram Sabha meetings only. The rest of the activities are looked after by her son, who is a politician.

The workers shared that the NREG Act is a good relief to them as in the agricultural operations the wage is low and also there is no scope for sustainable employment to all. They demanded that the activities under the NREG Act should be planned and implemented every year and employment should be given to at least one member in each family in the rural area, they added.

Vanagiri Village *Panchayat*

Vanagiri Village *Panchayat* is in Sirkali Block of Nagapattinam District. It is a multi-caste village located in the coastal area. Patinavar (Fishermen Community) is the majority community. Padaiyachi (Vanniyar), Naidu and SC are the other main communities of the Village *Panchayat*, Vanagiri. There are six hamlets, namely, Keela Vanagiri, Mela Vanagiri, Naganathamkoi, Palayagaram, Eramapalayam and Dosaikulam. It is a big village having a population of about eight thousand citizens.

Agriculture and fishing are the main occupations in Vanagiri *Panchayat*. In the year 2006 when the NREGA was introduced in the state of Tamil Nadu, in the District of Nagapattinam, Vanagiri Village *Panchayat* was the first Village *Panchayat* where the NREGA programme was commenced on 02.03.2006.

The Gram Sabha meeting was convened to select and prioritize the works under NREGA and the villagers listed desilting of tanks, maintenance of channels and road work in their hamlets. Moreover, as the villagers suffered due to entry of sea-water during the recent tsunami disaster, there was a suggestion to construct a protective bund along the coastal area so that the salination of agricultural land due to entry of sea water could be prevented. As the majority of the villagers preferred the construction of the protection bund, the proprietor of one the shrimp farm which is established along the wasted area came forward to spare a 30 meter length of his own land so that the construction would be purposeful.

The protection bund was constructed at an average height of about 2½ meter which will not only prevent the entry of sea water but also protect ground water and agricultural land from salinity. Daily about 350 workers, mostly women, are involved in the work. The turn out of workers was very low during the first week of the implementation. Later, realising the individual as well as the community benefits, the community extended its cooperation and the workers turned out in large numbers and in the year 2006-2007 other activities like maintenance of drainage channel and inlet channel and three minor irrigation tanks have been undertaken. So far (up to July 2007) Rs.11.00 lakhs has been utilised for the implementation of these activities, the *Panchayat* clerk explained.

The President shared that though desilting of tanks and maintenance of channels were the works demanded by one section of the community, the serious threats of salination of ground water, entry of sea water into the farm area and the pollution of soil were realized and the construction of a protection bund was preferred by the majority. After the completion of this work, the desilting and maintenance of water bodies have been undertaken, he added. The researcher found the sensitization among the community members in respect of ground water management has been steadily enhanced after the tsunami. And when the Village *Panchayat* was entrusted with the responsibility of NREGA implementation, they rationally acted to protect and promote ground water conservation.

In the context of failure of the state institutions in managing the commons and natural resources governments seek an alternative. It is natural that they have to dig into the past and trace it from history. Communities are effective managers and they manage the natural resources by following community laws. The community once had experts for this purpose. Till the introduction of the 73rd Amendment to the Constitution of India some of the commons were managed by the government and some were abandoned. The New *Panchayati* Raj System has created space for such activities within the domain of the *Panchayat*. The *Panchayat* Act provides only guidelines. The leaders who have got commitment and sensitivity have done commendable work. Lot of innovations are being done by the women leaders. It raises the hope that *Panchayati* Raj Institutions can do this kind of activities.

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ROLE OF AGRICULTURAL UNIVERSITIES IN GROUND WATER CONSERVATION AND SUSTAINABLE USE

J.S. Samra* & P.S. Minhas**

Introduction

Water for drinking, domestic utilities, irrigation and environmental services is very crucial for supporting growing population, especially of Asia. Ground Water is the preferred quality utility since it gets filtered during the process of recharge and is expected to remain uncontaminated for centuries. Irrigation is one of the largest users of Ground Water and is contributing about 70% of the total irrigation in India. Shallow water table and water logging in states like undivided Punjab led to digging of 30-40 metre wide-open drains during 1960s. Subsequently, public investments into rural electrification, connectivity and improved agricultural technologies attracted private investments of farmers for drilling bore wells. Large area under high yielding varieties of rice and wheat lowered water table and this vertical drainage was beneficial in improving overall productivity, desalinisation and reclamation of alkali soils. Ground Water, being available on demand, led to precision and input intensive agriculture. In some parts, even canal irrigation was abundant in favour of ground water irrigation because of its compatibility with highly mechanized intensive agriculture for realizing very high cropping intensity. Overall productivity of ground water irrigation is 1.5 to 3 times higher than the other. At present there are about 21 million ground water abstraction structures which amounts to the private investments of farmers of Rs.1050 billion at an average rate of Rs.50,000/structure. Therefore, proper management of ground water is uppermost for securing livelihoods and income of the farmers. The overall development of ground water resources in the country has so far led to the following scenarios that need to be taken seriously for the sustaining agricultural productivity.

Ground water Over-Exploitation

Convenience, efficiency and high productivity of ground water irrigation has led to overexploitation with the consequences that:

- Administrative blocks categorized as 'Over-exploited' or 'critical' have increased annually now total about 1065 (18% of the total). If such a trend continues, then one-third of the blocks in the country would come in the 'semi-critical / critical/OE' categories within two decades. One estimate puts a quarter of India's harvest at risk from ground water depletion. Over 50% of these blocks are located in six states namely Gujarat, Haryana, Punjab, Tamil Nadu, Karnataka and Rajasthan. The magnitude and spread of over-exploited blocks poses serious equity concerns warranting comprehensive development and management policies encompassing all uses and sources of water.

  Also the falling water levels with overexploitation demand additional private investments e.g. in Punjab about 30% of one million centrifugal pumps have been replaced by submersible pumps @ Rs.1 lakh each due to depleting ground water resources. Each rural household around Coimbatore used to have an open well which they deepened year after year due to fall in water table and now farmers are drilling within those open wells further up to 250 m depth. They are cultivating water-guzzling crop of banana, which leads to failure of pumps within 3 to 4 years and in this way the annual average replacement cost comes to about Rs.4000/ha. The farmers opined that large investments can only be recovered

*National Rainfed Area Authority, NASC Complex, Pusa, New Delhi-110012
**Natural Resource Management Division, ICAR, KAB-II, Pusa, New Delhi-110012

through banana cultivation and, therefore, it has become a vicious circle of investments.

Similar situation has been noticed in Kolar district of Karnataka which is not having any perennial river for canal water. During 2006, about 300 bore wells were drilled by one company and following features are very revealing: i) Minimum drilling depth was 200 m, ii) 80% cases were in the range of 200 to 300 m, iii) 20% cases were more than 300 m, iv) Average drilling cost alone was Rs.1 lakh, v) 60% was the success rate which is one of the causes of distress, vi) cost of installation of a complete bore well is Rs.3 lakh and vii) They are using 20 HP motors and 30 stages submersible pumps which consume very high amounts of electricity. There are many examples of overexploitation and desertification processes. This phenomenon requires recharging of ground water resources with every drop of water.

- Contamination of ground water from geogenic toxic or unwanted chemicals like arsenic, fluoride, selenium and iron and related food safety issues.
- Saline water intrusion from various sources and courses like seawater in coastal areas, salt water from geogenic formations and aquifers, re-entry of drainage waters or mismanagement of irrigation systems in arid areas.
- Pollution of ground water from anthropogenic activities like agriculture, wastewater disposal and industrial discharges.

Ground Water Under Utilization

On the other side, ground water resources in the eastern U.P, Bihar, Jharkhand, Orissa and some other isolated parts in the country are underutilized. These areas are having high potential with low productivity and are future hope for food security. However, proper designing of bore wells, efficient utilization of water and micro irrigation can go in a long way for optimization through multiple uses.

Keeping the above in view, it can be stated that ground water utilisation through run away growth of tube well irrigation in the country has created agrarian boom with massive gains in agricultural productivity and livelihood benefits. But the boom may not sustain if the complexities of ground water governance and solutions there-of are not found with the involvement of inter-disciplinary scientists along with the other stakeholders i.e. planners, managers and farmers alike. Lesson learnt due to above referred over/under-exploitation should become a part of planning process. Agricultural universities and other institutions have a large role to play in the development and management of water in the country. It is in this context that several of the 41 State Agricultural Universities (SAU) in the country are involved in education, research and extension in the field of ground water management.

Role of SAU's in Ground Water Management

Presently in most of the State Agricultural Universities where courses on BSc (Agriculture/Forestry), BE/BTech/ME/MTech (Agricultural Engineering) are offered, there is all likelihood that these SAUs are involved in development/management of ground water in the following ways.

- Teaching by offering courses
- Research and development work done
  - Through independent research of students.
  - Through independent research of faculties.

- Through network project of AICRPS
- Through ICAR adhoc projects
- Through DST/ISRO/MOWR/other organizations' sponsored projects
- Collaborative research with Central Ground Water Board and State Ground Water Organisations.

Teaching and Courses Offered in SAUs

A good number of courses are offered for BTech/BE (Agricultural Engineering) students in the field of ground water development and management. These are Ground Water Hydrology, Irrigation and Drainage Engineering, Soil Water Engineering etc. The main contents covered under these subjects are hydrology of ground water; its occurrence; types of aquifers; types of wells; types of tube wells; hydraulics of wells; discharge of wells; pumping from wells; design and construction of wells; water lifting devices operated by human power, animal power, mechanical power and other non conventional sources of power like wind and solar energy; different types of pumps, their design and efficiency etc.

Similarly BSc. Agriculture and Forestry under graduate students study the subjects of soil-water-plant relations and irrigation theory and practice etc. In these subjects, students are made familiar with ground water hydrology and importance of ground water and its management for irrigating different crops through different water application methods/ devices, besides all other aspects of irrigation sciences.

Students of ME/MTech.(Soil and water engineering / Irrigation and drainage engineering/Water management /Water sciences etc.) also learn advance hydrology and hydraulics of ground water including numerical methodologies ground water exploration techniques etc. also are being taught at SAUs to post graduate students. Different aspects of ground water such as its management through conjunctive use, pollution studies of ground water, its judicious use for crop productions and sustainability etc. are covered. Basics of ground water recharge and modelling aspects etc. are also covered during postgraduate studies. Design and fabrications of water lifting devices/ pumps/ turbines etc. to lift ground water are also covered during PG studies.

In some universities elective courses are also offered in the field of ground water during PhD courses. Besides these regular courses, where diploma courses are offered, they also cover elementary knowledge in the field of ground water hydrology to their students.

Research and Development in the Field of Ground Water by SAUs

It is compulsory for the students pursuing post graduation in SAUs to conduct research/ experiments and to submit a thesis at the end of their course for completion of the degree. Some of the students of MSc Agriculture and students of ME/MTech in soil and water engineering / irrigation and drainage engineering / water management / water sciences etc. take their research in the field of ground water hydrology and management, soil-water-plant relations, ground water contamination etc under the guidance of a faculty. Research papers are also produced from thesis and get published in referred journals and proceedings of seminars/ symposium etc. Some students who join for PhD in above subjects also conduct research in the field of ground water development and management. The qualities of research contributions made during PhD studies are rather of very high standard and most of them publish research papers in referred journals and proceedings of seminars/ symposium etc besides a PhD thesis.

Faculties of college of Agriculture/ Agricultural Engineering and some times college of Forestry of all SAUs take independent research in the field of ground water management or sometimes part of their studies are on ground water management. In these projects the sponsorship is by the parent university. They produce technical manuals or bulletins along with research papers in referred journals and proceedings of seminars/ symposia etc. They also document the results obtained from laboratory studies or experiments conducted for the under graduate and post-graduate students and produce research publications.

Network Projects of AICRP on Ground Water Utilization

The All India Coordinated Research Project on Optimisation of ground water Utilization through Wells and Pumps running at different SAUs funded by ICAR is striving to make humble contributions in the area of ground water development and management. In the project, research is being conducted in different fields of ground water management for its optimal utilization for irrigation namely assessment, planning and optimal utilization of ground water resources on regional level, optimal plans for conjunctive water use, efficient abstraction machinery and infrastructure, artificial ground water studies, ground water pollution through agrochemicals and industrial effluent, etc. There are nine network centres located at different SAU's namely PAU, Ludhiana, GBPUAT, Pantnagar, MPKV, Rahuri, JNKVV, Jabalpur, WTC, TNAU, Coimbatore, JAU, Junagadh, MPUAT, Udaipur, IGKV, Raipur, and RAU, Pusa covering different geo-hydrological conditions of the country and they have accomplished research work through various experiments under each of the five themes of model technical program of the project. Very practical and viable recommendations have emerged and also equipments have been developed under the scheme for effective utilisation of ground water resources. Also, a large number of publications and media coverage have been done in these network schemes.

Network Projects of AICRP on Water Management

The All India Coordinated Research Project on Water Management is running in 25 centres out of which 23 centres are located in State Agricultural Universities covering different agro-ecological regions of the country. Out of its fives major themes, one deals with the "Conjunctive Use of Surface and ground water for Sustainable Crop Production". Most of the cooperating SAUs work on this aspect in network mode. Also, several SAUs are working on development of efficient water distribution and irrigation equipments (micro irrigation) using ground water. A good amount of research output in terms of publications and recommendations have been evolved from these projects. There has been a large number of demonstrations in these aspects.

Network Projects of AICRP on Use of Saline Water

This All India Coordinated Research Project on "Management of Salt-affected Soils and Use of Saline Water in Agriculture" has 8 centres, which are located in State Agricultural Universities covering different agro-ecological regions of the country. The major research efforts are concentrated on themes like sustainable use of saline and alkali ground water in agriculture and agro-forestry systems; conjunctive use of surface and saline ground water, viable options for using sewage and industrial effluents with minimum ground water contamination, skimming technologies for extracting better quality water floating over saline water, rainwater recharging and reuse etc. A large number of field demonstrations are also conducted through its outreach programmes in terms of ORPs.

ICAR ad-hoc Cess Fund Projects

Indian Council of Agricultural Research sponsored Agricultural Produce Cess Fund adhoc projects to faculties or Scientists or Professors of state agricultural universities during last many years. Under these ICAR adhoc projects, university faculties were sanctioned several projects in which ground water development and management aspects were covered. These adhoc projects aim at developing location specific ground water management methodologies, policies for enhancing crop production and sustainability of the eco-system.

DST/ISRO/MoWR/ Other Organization's Sponsored Projects

Faculties or Scientists or Professors of State Agricultural Universities are also getting several research projects from other sponsored organizations such as DST/ ISRO/ MoWR etc. Under some of these schemes, university faculties are studying several ground water development and management aspects. These projects aim at developing location specific ground water management methodologies, policies for enhancing crop production and sustainability of the eco-system.

Collaborative Research with Central and State Ground Water Organisations.

In some of the research and development aspects of ground water, State Agricultural Universities faculties work in collaboration with Central and State Ground Water Organisations. These organisations share their vast database with the faculties of SAUs and the expertise of these faculties are utilized for solving a particular problem of an area or region and in developing management policies of ground water in different geo-hydrological situations. Presently, there are linkages of faculties of SAUs with other National or International institutions on issues of mutual interest in ground water management studies.

Epilogue

Typical characteristics of ground water in terms of its prevalence, reliability in supply and quality has led to its widespread use by both rural and urban sectors. Effective management of ground water resources requires optimal balancing of demands of its users and long-term maintenance of this natural resource. Ground water science is expected to help in its accurate assessment; understand specific susceptibilities of the aquifers for abstraction and contamination and also the interactions between surface and ground water. At the same time, proper ground water management also requires integration of science into management decisions. Thus narrowing of gaps in the perceptions and understanding of scientists and managers is urgently required in view of increasing pressures on ground water resources of the country. SAUs are expected to play a key role in obtaining sustainable and acceptable solutions to ground water challenges but presently the major role of different SAUs in the field of ground water is mainly to offer courses for professional degrees and research activities of AICRP centres, but no other activities are compulsory or have much binding on them. Therefore there seems to be an urgent need to upgrade and strengthen the quantity and quality of research attempts made in the field of ground water. SAUs also need to be sensitised for more serious and precise collaborations with other organisations working on ground water management.

ROLE OF RURAL INSTITUTIONS IN GROUND WATER CONSERVATION AND SUSTAINABLE AND EQUITABLE USE

Vishwa Ballabh*

Introduction

Ground water is a significant source of irrigation in India and accounts for more than half of net irrigated area in the country. The importance of ground water as a source of productivity and livelihood gains can hardly be over-emphasized. Besides, ground water is also major source of drinking water, particularly in rural areas. The pattern of ground water development has, however, created a number of sustainability, equity and efficiency concerns. Ground water exploitation levels are alarming in many areas. The development of ground water resource has been primarily through private initiative. However, indirect government incentives in the form of rural electrification, electricity subsidy, credit policies and promotion of ground water-based irrigated agriculture through public tube well programmes helped in rapid expansion of ground water irrigation in the country. With the population growth, the demand for cereals and food crop increases, which in turn leads to increased water demand for irrigation. The extraction of ground water for intensive commercial agriculture has made qualitative and quantitative changes in the value of ground water resources. From being a source of protective irrigation, meaning watering only to tide over vagaries during the monsoon failure and winter period, the ground water use in agriculture has changed to become the most critical input in commercial production (Shah, 1993). With the commercialization of agriculture, water has become a tradable commodity. Water markets have developed in many parts of country even in areas where agriculture productivity is still very low such as north Bihar (Shah and Ballabh, 1997). The massive private investment in ground water irrigation, coupled with public investment in surface irrigation systems helped India to achieve self sufficiency in cereal production. Today, India produces and consumes about 210 million metric tons of food grains each year. Questions, however, have been raised about the nation's capacity to increase and double its production to over 340 million ton by the year 2020 due to water scarcity (Rosegrant et al 1999). In fact some researchers have begun to question the sustainability of ground water-based irrigated agriculture. In this paper an attempt has been made to examine the role of rural institutions in development, conservation and distribution of ground water in agriculture sector.

Sustainable Water Management

The Brundtland Report defines 'Sustainable Development' as development that meets the needs of the present generation without compromising the ability of the future generations to meet their own needs (World Commission on Environment and Development, 1987). Therefore, sustainable development suggests the selection of economic development strategies which protect the eco-system. It is increasingly being realized that past and current strategies are neither desirable nor sustainable in the long run. However, sustainable development is interpreted differently by different people; economists believe in the relative scarcity of resources whereas the ecologists, in their absolute scarcity. These beliefs tend to influence the variations in the perspectives and the corrective actions recommended. For example, the economists argue that sustainability will require a significant expansion in agriculture, forestry and other research to implement more environment-compatible technologies, environmental monitoring and assessment and design of new institutions and organizations to internalize external costs (Norgaard, 1991). In contrast, the environmentalists believe that corrective course of action should be the reduction of

*Professor, School of Business and Human Resources, XLRI, Jamshedpur (Jharkhand)

the overall economic activity. Environmentalists' progressive goal might be to lift the poor and bring them closer to rich through the adoption of non-polluting, efficiency enhancing technology (Batie, 1992). The imperatives of strategies for sustainable water development is that protection of the environment is so complex and gigantic a task that no amount of tinkering with markets and incentive structures may be enough for it, especially due to massive uncertainties and variations in the impact of changes in ecological conditions in different areas. Thus, the main plank of the environmentalist point of view has been the maintenance of the resource base, minimizing increased water use and limiting it only to the incremental water resource added through precipitation and saved run-off of rivers in a region. The economist, in contrast, advocates correct structure of incentives so as to produce solution oriented technologies, institutions, corrections in the market and in internalizing the externalities (Repetto, 1986). Operationally, the difference in pre-and post-monsoon ground water table indicates incremental water built due to rains and recharge through seepage of lakes, rivers and water streams, which could be used without affecting ecological balance of a region. The actual utilization of ground water, however, would depend upon the nature of technologies and costs and benefits associated with these technologies. The private and social cost and benefits are likely to be at variance if there are externalities associated with ground water use. Robust rural institutions should help regulate ground water use and management in sustainable and equitable manner where equity is defined in terms of accessibility of water by everyone. The rest of the paper reviews experiences of rural water institutions in use and management of ground water in past two –three decades.

Experiences in Ground Water Development

Faced with chronic food shortages, Government of India launched several programmes to increase food production in the country in early 1960's. One of these Programmes was development of ground water through public tube wells in various part of the country, particularly in north western part, where green revolution had taken early roots. The STWPs original objective was to supply ground water irrigation efficiently and equitably to all the farmers in their command areas. Though the STWP's suffered from inefficiency and corrupt practices they had several positive impacts in terms of (i) demonstration effect, (ii) bringing electricity and reducing transaction cost of establishing ground water based irrigation system in the village economy and (iii) expansion of green revolution technology. Soon, however, it become clear to the farmers that they could not realize the potential of green revolution technology if they remain dependent on public tube wells and thus began to invest their own capital in ground water based irrigation systems. This led to launch of subsidized credit programmes for the development of ground water primarily to make sure that small and marginal farmers should not be deprived of access to ground water irrigation. As the ground water irrigation was spreading across the length and breadth of the country, the supply of electricity became a limiting factor. To overcome this constraint, farmers moved to diesel pump sets, which eventually meant increased cost of ground water access. Concerned with these facts, several NGOs experimented with group and collective ownership of tube wells, whereas State Governments responded by extending the public tube well programmes even in areas where green revolution had yet not taken roots and in areas such as Gujarat where farmers had identified institutional mechanism to overcome lumpy and heavy investment constraints through tube well water companies (Shah 2004). As ground water development started expanding, there was concern about equitable access of resources among different groups of farmers. Both civil society (NGOs) and governments responded by extending the concept of group and cooperatives tube wells and allocating resources for public tube wells.

However, a silent revolution that had taken place, which was not noticed by the researchers and academicians till middle of the 1980's was the development of ground water markets, though unrecorded history and keen observers of agrarian economy had already noticed buying and selling of ground water since at least mid 1950's. Thus, three types of institutions are involved in ground water use and management. These are (i) public tube wells (ii) group or cooperative tube wells (iii) water markets.

Public tube wells today are in precarious condition and in most of the states either they are defunct or because of financial and other constraints these tube wells are being handed over to user groups by the State under turnover of public tube well programmes launched by various State Governments. The experiences with group and cooperative tube wells in various parts of the country were equally disappointing and in many parts of the country they did not succeed. Thus a large part of ground water use today is in private domain where individual or group of farmers invest in WEMs and determine the use and abuse of ground water resources. Thus, functioning of water markets has become sole determinant of sustainable and equitability of ground water use. Therefore, understanding of the nature and functioning of ground water market is necessary for determining suitable public response. Three issues are important:

- Are existing institutions promoting safe limit of water extractions in particular context;
- prevent inequity in water access ,control and use; and
- Are the resources used efficiently and in most productive manner ?

It is obvious that in a country like ours, experience cannot be uniform. However, it is quite clear that barring few areas such as north and eastern India, the progressive decline of decline of ground water is alarming in most part of the country. The rate of exploitation of this resource is outstripping the rate at which it is being replenished. The development of water markets has a positive impact and water is made available to even those who do not have capacity to invest in deep tube wells. However, it has also adverse consequences in terms of sustainability of resources. The discourses on development of water markets in the Indian context have largely ignored the impact of water markets on the sustainability of resource base. Further, competitive deepening makes access to ground water increasingly skewed in favor of large, resource-rich farmers leaving the small farmers at increasing disadvantage in sharing the benefits of well irrigation (Vaidyanathan, 1999; Shah, 1993; Prakash and Ballabh, 2004). Competitive deepening of wells for irrigation also adversely affected quantity and quality of drinking water available in rural areas. As a result, the number of `no sources' villages is steadily increasing over time (Agrawal and Narain 1997). Another dimension of development of water markets in the Indian context, which is often ignored, is that in many areas water markets are not yet fully developed and unequal trading relationship prevails between sellers and buyers which results in the exploitation of buyers not only through the mechanism of price but also through non-price mechanisms (Shah and Ballabh, 1995; Janakarajan, 2004; Prakash and Ballabh, 2004). This pattern of development has raised a number of issues related to sustainability, equity and efficiency ground water management. Some of the notable responses to correct the situation are described briefly below.

Responses of NGOs

Concerned with equitable access and control of ground water resources, Indo-Norwegian Tube well Programmes promoted group tube wells in Deoria and Vaisali districts. Initially, these tube wells succeeded in bringing tube well technology, electricity and green revolution technology. This led to intensification of agriculture and created marketable surplus among small and marginal farmers. Once these farmers generated their own surpluses, they invested in private tube wells individually. As a result, water markets developed and the group and cooperative tube wells could not compete with private individual tube well owners. These tube wells became defunct and unviable. However, this did not deprive small and marginal farmers' access of irrigation. In fact, markets became more reliable and economical sources for irrigation water (Ballabh, 1987) and it also reduced transaction costs. The development of water markets in some of the areas of this region was further boosted by government policies such as free boring schemes etc.

The Sadguru Water and Development Foundation (SWDF) has been working in the eastern part of Gujarat since 1974. The heterogeneity of the resource base in this region demands that any development intervention take into account the location – specific nature of the resources and that the people understand the management of the resources. Based on their experience spanning over thirty years, SWDF has designed a unique way of intervening in the area for launching developmental projects. The co-operative lift irrigation scheme is the core of this overall strategy of intervention.

SWDF has so far developed around 227 such lift irrigation projects. This is at a time when many developmental experts advocate privatizing the water resources. The proponents of the privatization argue that it is an economic good and therefore a common framework of governance could be developed, treating water as a commodity which could be bought and sold and has a recognized value. The opponents, however, believe that while market pricing is a way of regulating use of a scarce good like water, it is blind to anything that cannot enter the market place. So while in theory one could specify all direct and symbolic values in economic terms, not all of them could realistically be reflected in the prices of economic commodities. The risk is that the economic value of water would mean simply its partial value as a commodity. The loss of access - especially for the rural poor - to all the rights in the bundle that are not reflected in the commodity market is a legitimate cause for concern. The SWDF has recognized these aspects of water use and management and has developed an institutional framework within which common property right of the village community is constituted.

The basic premise and overarching concern of SWDF has been to improve the living conditions of the tribal communities, in strengthening the livelihood system in the villages to the extent that it could not be achieved without improving the natural resource base, and that is the management of resources like water, attention has to be paid to the water which is crucial resource for the people in the area. The second aspect of Sadguru's intervention is that peoples' participation is essential for effective delivery and sustenance of the programme. The compulsion to leave the village in search of wage labour could only be addressed by alternative means of livelihood based on agriculture which needs a measure like water resource development for its sustenance. For agriculture to be a viable preposition in this rainfed area, the first intervention needs to be in irrigation. Whether the decision to start with the construction of lift irrigation scheme was the outcome of a clear understanding of this causal linkages or an expression of blind faith in the success formula of the green revolution is a moot point (Ballabh and Thomas, 2002).

IRMA had taken up an action research project which consisted of several projects. One of these projects was to turn over management of public tube wells under Gujarat Water Resources Development Corporation (GWRDC) to the farmer's organisations. The objective of the turn-over programme of the GWRDC was to facilitate the emergence of local farmers' groups to take-over the management functions of tube wells, and thereby strengthen local management capabilities and institutional structures in order to improve the efficiency and performance of tube wells. After the turn over, farmers now get assured supply of irrigation water and take strong interest in the management of irrigation co-operative society. Because of assured water supply, farmers get higher crop yields and production than that obtained earlier. The area under irrigation has also increased to a considerable extent. Regular and assured supply of irrigation water has compelled private tube well owners to adopt a more competitive rate of water pricing.

The whole process of formation of irrigation cooperative society and its registration involved tremendous learning in terms of understanding interactions with the government, bureaucracy and local conflicts. It was realized that the main problem was how to interact and deal with government bureaucracy which still does not recognize local people's initiatives and is driven by rules and procedures that promote delays and corruption. A significant amount of time and energy was spent in arranging the take over of the tube wells from the corporation. It was because of the high stakes in the new projects that farmers even agreed to pay off the outstanding debts with the corporation. So, the project not only made these tube wells run viably but also helped the corporation to recover its dues (Balllabh et al, 2001).

Other programmes include the participatory ground water management programme of VIKSAT Ahmedabad; water resource development, watershed development and ground water recharge programmes of AKRSP in Surendra Nagar and Junagadh districts; the ground water recharge programme of Shri Vivekananda Research and Training Institute working in Kutch; water resource development and watershed treatment activities of Sewa Mandir in Udaipur District of Rajasthan and the local water harvesting programme of Tarun Bharat Sangh in Alwar, Rajasthan. The Nirmal Neer programme of the Swadhyaya Parivar is another programme that has been advocating and executing water conservation programmes purely with voluntary effort.

Similar experimentation has also been done by other NGOs in other parts of water scarce regions. It has been noted by scholars that many of these experimentations had no direct links to managing water scarcity. These were essentially aimed to create more responsible attitudes to water users' communities and build viable irrigation organisations (see for details Shah, 2004). Some NGOs however, focused attention towards water scarcity and made attempts to conserve water *in situ* by developing appropriate institution and technology. Many of these, however, found that intensity of water use went up after implementation of water conserving technologies and institutional mechanisms to regulate the use of water disappear after the withdrawal of the NGOs. The scale and scope of operation was also extremely small and hence their capacity to make impact at aggregate level was also not significant.

By and large, NGO water management initiatives display a wide spectrum of activities from water development to watershed development and management to watershed treatment, including wasteland re-vegetation to water harvesting and ground water recharging. The scale of implementation of water management interventions shows significant variations across agencies. But, many NGO water management activities are weak on the conceptual front. They touch upon only a few aspects of water management. As regards physical management strategies, they only focus on supply side management. No efforts are being made to alter social systems, to affect changes in water use practices, and efficiencies, and ultimately manage the demand.

Response of State

The State has generally responded by enacting laws and administrative regulations. The regulatory approaches are aimed at preventing ground water over-draft and pollution of water bodies. Several states in the country have passed legislations to control and regulate the over-development of ground water resources in accordance with the Model Bill. They were, by and large, command and control approach to effect changes in the resource use. Over and above, they are blanket legislations and do not capture the potential variations in the overall physical, social, economic, cultural and institutional settings, which would determine the needs of different localities and regions. As a result, they are often hydrologically less meaningful and socially and politically non-viable (Moench 1995; Kumar, 1995). A model bill proposed by central government has generally being ignored by State Governments. State Governments have also been reluctant to enact property laws which are being advocated for efficient functioning of ground water markets. It should be noted that the transaction cost of enforcement of property right is likely to outweigh benefits. This may result in remedy worse than disease.

The pollution control norms, set by the State Pollution Control Boards, have largely been ineffective in controlling water pollution due problems in implementation due to the following reasons. First, the institutional and administrative capabilities to monitor water quality are increasingly becoming inadequate (Ballabh and Shanmugham, 1999). Secondly, the traditional water treatment plants are incapable of treating the new, toxic chemicals industries produce. Third, the Municipal authorities and small industries, which are major sources of pollution, do not have financial resources to invest in treatment plants that are prohibitively expensive. Fourth, the pollution control agencies have not been given powers by the provisions of the act to penalize the violators, and hence are to be prosecuted in the normal course in judicial court (Bhatt, 1986). Many scholars concluded that State response to the twin problems of depleting and deteriorating ground water has been inadequate and its different organs have often worked at cross purposes (Shah, 2004). State has also failed to create appropriate environment for community action in management of water resources in general and ground water resources in particular (Ballabh, 2007, forthcoming).

Assessment of the Impact

The above discussion brings out clearly that the existing rural ground water management institutions are unable to tackle the problem of ground water deterioration both in terms of quality and quantity. Approaches are needed that would allow integration of various physical systems affecting water availability such as river systems, ground water, catchments-for realistic assessment of the supplies, demand and the potential impacts of different water management interventions. The approach should also allow integration of the socioeconomic systems affecting water use for analyzing the sectoral demands and their dynamics of interaction so as to ensure effective water allocation decisions. As demand for food grain will increase, the pressure on ground water resources would further strengthen and therefore it is important to identify institutional mechanism capable of managing both demand and supply side factors to reduce stress on ground water resources. Table 1 provides tentative and broad assessment of existing ground water management institution in conservation and use of ground water resources.

Table 1: Assessment of Rural Institutions in Conservation and use of Ground water Resources

Particulars	**Water Abundant Areas**	**Water Scarce and Fragile Areas**
(i)Regulatory mechanism (like siting of wells, electricity connections and subsidized credit)	Not required, subsidized credit may help promote ground water development	Ineffective, farmers find alternative sources of credit and energy sources.
(ii)Rationing electricity and Pricing	Electricity generally not available, rationing not required, provision of electricity may user growth in agriculture sector.	Effective but alternate high cost substitute are used by the farmers.
(iii)NGO's ground water development programmes	Initially beneficial to farmers, now not required	Helped access of ground water to resource-poor farmers, but conservation objectives not realized.
(iv)NGO's / Governments water conservation programmes	Generally not required but better management may help reduce drainage congestion and water logging problem.	Water conservation increased but increased intensity of water utilization.
(v) Public policies for water users Association	Not required	Not available and generally not supported by water resources departments.
(vi) Water Market	Well developed and relatively more equitable access	Developed and vibrant but sellers extract monopoly rent

It is evident that existing water management institutions do not help conservation of ground water resources. It is argued that in most of south Asian countries, State is soft, which prevents them from taking appropriate measures such as water and electricity pricing to align the cost of lifting ground water resources to their scarcity value (Shah 2007, forthcoming). On the other hand, scholars like Professor Vaidyanathan and Iyer argue that ground water need to be treated as a community resource and it should be brought under regime of stringent regulations. This requires enacting and changing laws relating to ownership right over ground water, enactment of regulatory bodies and rationalization of power tariffs (Iyer 2007, forthcoming). There are still others who advocate indirect approaches to tackle the problem of ground water depletion. These scholars advocate thinly spreading of canal water system, recharging of wells, watershed management and putting indirect control over ground water extractions through restrictions or electricity supply may help in arresting ground water resources. As indicated above, these approaches at best help partially and affect only supply side factors. One need to take into account demand side factors and also every attempt need to be made for improving the efficiency of water use in agriculture sector. Overall, it may be concluded that we have not yet found a viable solution to arrest the degradation and depletion of ground water resources.

Concluding Remarks

There is no doubt that ground water today contributes more than surface irrigation system to the agrarian economy. The overview in this paper highlights the precarious nature of ground water and proves that the present form of management is unsustainable, unequal and detrimental to the resources-poor people, particularly those living in fragile areas. Many scholars have also condemned development of ground water markets and uneconomic pricing of electricity and other energy sources for the present condition. Contrary to the popular belief, there is empirical evidence which suggest that the development of ground water market has been beneficial for the resource-poor farmers, which enables them to access this precious resource *albeit* at higher prices. There is need to develop ecological perspective in ground water use and management which takes into account land use, local ecology and agrarian production relations and evolve institutional structures capable of arresting depletion of this precious resource.

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ITC's WATERSHED DEVELOPMENT PROGRAMME

Ashesh Ambasta*

Context

To ensure long-term business competitiveness, it is becoming increasingly essential for corporates to pursue the conservation and management of natural resources to sustain long-term and enduring value creation. In the context of ITC, amongst India's largest exporters of agri-commodities, with multiple value chains across the country, the availability of water is vital, but is woefully inadequate. India's present per capita water availability is 1,170 m³/person/yr, classifying it as a water-stressed country.

Some dry and despairing facts stare India in the face :

- One-third of the country is always under the threat of drought, not necessarily due to deficient rain but because of uneven occurrence.
- 77% of the geographical area consists of arid, semi-arid and dry sub-humid regions that are highly prone to land degradation. Drought-like situations occur at least once or twice every five years due to poor monsoons.
- Nearly 90% of annual precipitation is lost due to surface run-off and only 10% is harvested.
- Though the utilisable surface water potential is estimated at 1,869 km³, only 36% can be put to beneficial use due to physiographical and topographical limitations as well as lack of water harnessing technologies.
- Ground water sources meet almost the entire rural demand for water and account for more than 45% of total irrigation. It is the only water source during droughts.
- 43.5% of the total geographical area is agricultural land of which 59.4% suffers from varying degrees of soil degradation and 67% is subject to severe moisture-stress for 5 to 10 months of the year.

Against this backdrop, the criticality of the development and management of water resources cannot be overemphasized.

Situation Analysis

ITC's agri-business interests are spread across 9 states where it has forged long and enduring relationships with thousands of farmers over many decades. These partnerships have been mutually beneficial and have brought economic prosperity to partner farmers. However, most of these partner communities are located in agro-climatic zones that are especially susceptible to seasonality and typically face the following problems :

1. They operate in moisture-stressed semi-arid regions where agriculture is rain-fed and therefore exposed to the vagaries of the monsoons. The vulnerability of the agricultural resource base is exacerbated by fragile soils, irregular rainfall and stagnating productivity.
2. Ground water depletion is severe due to poor conservation practices and unrestrained extraction through bore wells. As a result ground water tables are falling and bore wells are rapidly drying up, further reducing irrigation potential.
3. The erratic rainfall pattern in the last few years combined with changes in land-use practices and patterns have resulted in successive years of large-scale crop failures.

*ITC Limited, Kolkata

4. Public and private investment in water harvesting measures has been negligible despite the huge potential for harvesting rainwater and its use for irrigation.
5. Unsustainable use of natural resources upon which agriculture depends, impacts critically on food security, with poverty, low agricultural productivity and environmental degradation feeding each other in a severe downward spiral.

Objectives

Of all the approaches that address the complex inter-relationships between natural resources and their impact on rural livelihoods, the integrated watershed development approach has emerged as the most successful strategy. ITC has adopted this approach as the basis of its own model. Over the past three years, the Company has consciously aligned its performance to the dimensions of the triple bottom line - economic, environmental, and social. Reflecting this commitment , ITC's model converges its social and environmental goals with the demands of its supply chains.

ITC's integrated watershed development projects are guided by specific objectives :

1. Increase biomass cover through revegetation of common and private wastelands.
2. Assist village communities through appropriate soil and water conservation measures to improve water availability for agriculture.
3. Strengthen community-based governance of biomass and water resources by initiating and intensifying systems of collective management.
4. Assist communities to effectively integrate agriculture and natural resources management and regulate demand for biomass and water through rules, regulations and mechanisms evolved by community institutions.
5. Attain 'water positive' status through rainwater harvesting, reducing freshwater intake, treating and recycling all wastewater to prevent pollution of freshwater resources and conservation of water to achieve the lowest specific water consumption per unit of production within its operating units and watershed development projects beyond the fence.
6. Optimise benefits of water resources created by watershed development projects through other appropriate interventions like integrated agriculture and livestock development, to provide sustainable off-farm livelihood sources.

ITC's Integrated Watershed Development Model

In order to attain these objectives, ITC adopts the following approach consistently throughout its project sites so that each element feeds back positively on the rest in a mutually reinforcing model :

1. *Eco-restoration:* In recognition of the need to maintain natural biodiversity, the projects improve the biomass and diversity of common and private wastelands through regeneration and revegetation initiatives and introduce appropriate mechanisms to improve productivity of marginal lands.

2. *Soil & Water Conservation:* The approach develops appropriate technologies that complement existing community knowledge to conserve soil, water and nutrients. These techniques are highly replicable because they are location-specific, use traditional methods and simple technology, rely on local material and are low-cost. These activities include the building and repairing of :

a. Continuous contour or staggered trenches based on the slope, loose boulder contours, earthen dams and earthen check dams to help regulate the velocity of water run-off and minimise erosion of drains.
b. Water harvesting/water recharging structures to build water storage capacities to secure agriculture.

3. *Sustainable Livelihoods:* The projects promote a combination of solutions for optimising water management and enhancing land productivity such as :

   a. Introducing technical land correcting measures like raising farm-bunds to check fertile top-soil losses and provide in-situ moisture conservation.
   b. Promoting water saving technologies through location-specific activities like building farm ponds, deepening open wells, building community wells, and drip/sprinkler systems for harvesting water and making it available for protective irrigation or recharging ground water.
   c. Propagating the diversification of rain-fed crops, improved agronomic practices, intensification of organic manuring techniques through demonstration plots, training and supervision.

4. *Empowering Grassroots Institutions:* Strengthening institutional arrangements is an essential component of the model, at the core of which is the formation of dynamic and functioning water user groups (WUGs).

   a. Participatory Rural Appraisal (PRA) exercises are conducted to identify the potential target group, its existing resource base and to create village micro-plans, including identification of optimal watershed initiatives. A bottom-up rather than top-down planning process ensures that potential stakeholders are active participants in the development process, not passive recipients. The WUGs undergo intensive training programmes in watershed management techniques and maintenance of the structures, as well as regulation of water-use and user charges.
   b. Village micro-plans detail the nature of interventions, their location, responsibilities for implementation at various levels and the financial outlay involved, including the extent and nature of contribution by the WUGs.
   c. The planning, implementation and monitoring of the programme is executed through peoples participation where the sustainability of the structure becomes the responsibility of the WUG – from budgeting, formulating rules and regulations for equitable water sharing and creating a corpus fund from user charges for maintenance.
   d. Robust documentation systems ensure a built-in, self-correcting, information and monitoring system. With the ultimate aim of creating a confident, informed, self-reliant and empowered community, the model promotes two types of community organisations at the village level as shown in the table below:

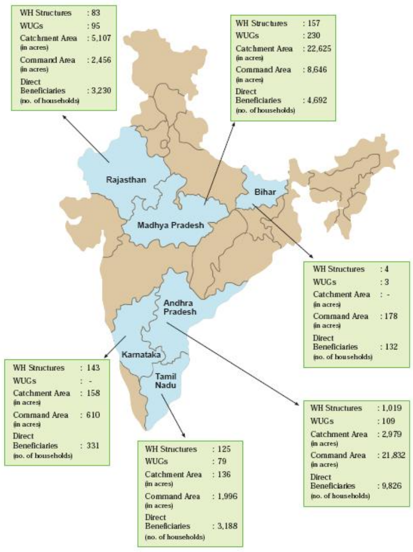
INSTITUTION	ROLES
Water User Groups	• Contribution generation for projects • Implementation, management and maintenance • Intra-group conflict resolution • Working as common interest groups for business-linked Watershed Plus activities – growing organic spices, medicinal and aromatic plants and other crops, horticulture, dairying, etc.
Watershed Association (formed by several Water User Groups)	• One-point access to the entire village • Developing and approving watershed plans and deciding priorities • Taking responsibility for management of common land structures • Inter-group conflict resolution • Responsible for generating corpus fund through revolving fund / loan recovery

5. *Public-Private Partnerships:* ITC recognises that its efforts at nurturing stable soil and moisture regimes is targeted at developing models of excellence in which community needs are met holistically, without creating a culture of dependency, through efficient delivery systems which are replicable. However, scale-up is only possible through collaborations that draw upon the managerial capabilities of the Company, the mobilisation skills of best of class NGOs and the vast resources of the Government. Therefore at every project site a concerted effort is made to draw upon these synergies.

Achievements

Geographical Spread

Starting with 3 projects covering 60 villages in 2001-02, the programme today covers 23 districts and 414 villages across 6 states in some of India's most moisture-stressed regions.



Watershed Development

The total area covered under the watershed programme by 2006-07 was 66,723 acres. Of this 31,005 acres of the catchment area were brought under soil and moisture conservation treatment and 35,718 acres of the command area were ensured of critical irrigation through the creation of 1,531 water harvesting structures. Of this command area, 3,949 acres were uncultivable lands which were brought under agriculture as a result of the availability of water. There were a total of 21,399 direct beneficiary households while 311,480 person-days of employment were created for the landless as a result of work on the construction and due to the increase in cropping intensity. The success of the project’s community mobilisation is evident from the number of functioning water user groups and from the fact that the community has contributed nearly Rs.248.69 lakhs (about 25% of the total cost) towards these projects.

WATERSHED DEVELOPMENT	Cumulative to 2005-06	2006-07	Total
WATER HARVESTING	56	98 24 31	**154**
STRUCTURES	29 104	6 35 295	**53**
Check Dams	10 146	24 25	**135**
Stop Dams	567	**538**	**16**
Large Percolation Tanks	81 -		**181**
Village Tanks	**993**		**862**
Nalla bunds (Earthen Checks)			**105**
Farm Ponds			**25**
Small Percolation Tanks			**1,531**
Renovation of WHS			
No. of Structures			
CATCHMENT AREA TREATMENT	1,208	4,185	**5,393**
Gully Plugs / Boulder Checks	134,604	222,273	**356,877**
Contour Trenches / Bunds (Cmt)			
COVERAGE (Acres)	24,973	6,032	**31,005**
Catchment Treated	26,064	9,654	**35,718**
Command Area	3,825	123	**3,948**
Land Reclaimed / Treated			
WATER USER GROUPS	302 4,656	214 5,088	**516 9,744**
No. of Groups No. of Members			
BENEFICIARIES	12,985	8,414	**21,399**
Direct (No. of households) Indirect	144,312	167,168	**311,480**
(Employment person-days)			

Watershed Development : Statewise Break-up of Activities

ACTIVITIES	Rajasthan	Madhya Pradesh	Bihar	Andhra	Karnataka	Tamil Nadu	Total
WATER HARVESTING							
Check Dams	4	87	1	1	4	12	**154**
Stop Dams	2	51	-	-	-	-	**53**
Large Percolation	9	3	3	102	5	13	**135**
Village Tanks	-	2	-	-	5	9	**16**
Nalla bunds (Earthen	1	2	-	160	-	-	**181**
Farm Ponds	3	11	-	647	129	72	**862**
Small Percolation	1	-	-	85	-	19	**105**
Renovation of WHS	-	1	-	24	-	-	**25**
No. of Structures	**8**	**157**	**4**	**1,019**	**143**	**125**	**1,531**

ACTIVITIES	Rajasthan	Madhya Pradesh	Bihar	Andhra	Karnataka	Tamil Nadu	Total
CATCHMENT AREA							
Gully Plugs / Boulder	61	4,777	-	-	-	-	**5,393**
Contour Trenches /	54,31	128,176	-	96,10	19,915	58,364	**356,87**
SOIL & MOISTURE							
Catchment Treated	5,10	22,625	-	2,979	158	136	**31,005**
Command Area (Acres)	2,45	8,646	178	21,83	610	1,996	**35,718**
Land Reclaimed / Treated (Acres)	1 5	649	-	3,284	-	-	**3,948**
WATER USER GROUPS							
No. of Groups	9	230	3	109	-	79	**516**
No. of Members	1,11	3,247	132	1,094	-	4,160	**9,744**
Local Contribution (*Rs. * Rs.1 Lakh =	23.4	110.37	0.16	89.73	5.48	19.54	**248.69**
BENEFICIARIES							
Direct (No. of	3,23	4,692	132	9,826	331	3,188	**21,399**
Indirect (Employment person-days)	91,09 7	192,210	-	10,70 4	13,750	3,719	**311,48 0**

WATERSHED PLUS	Cumulative to	2006-07	Total
INTEGRATED AGRICULTURE DEVELOPMENT			
Irrigation :			
Wells	106	69	**175**
Sprinkler Sets	325	89	**414**
Composting :	3,102	3,625	**6,727**
Vermi	1,663	948	**2,611**
NADEP			
Demo Plots :	947	450	**1,397**
IPNM & Varietal Demo	142	100	**242**
Others	502	1,525	**2,027**
IAP Training			
LIVESTOCK PROGRAMME			
No. of Cattle Development	72	77*	**77**
Breed Improvement :			
No. of AIs	34,673	52,506	**87,179**
No. of Pregnancies	10,654	22,275	**32,929**
No. of Calfings	3,620	9,839	**13,459**

* Includes CDCs already in operation

Impact

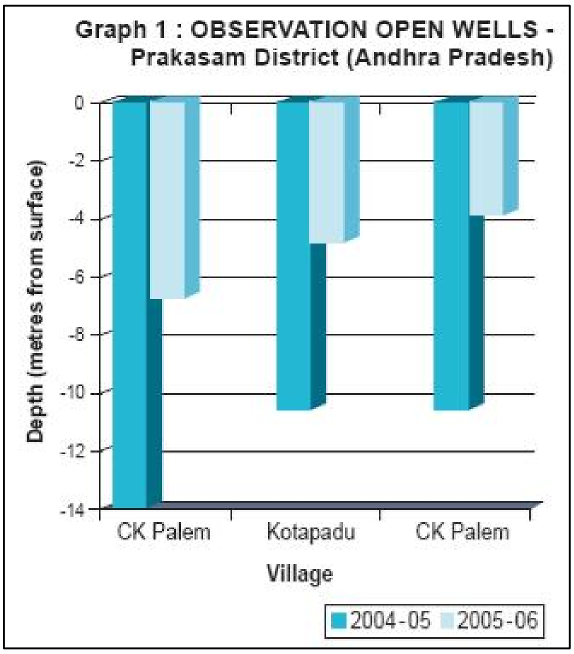
ITC has put in place a rigorous Management Information Systems (MIS) to assess the impact of its watershed projects. The reports generated from this MIS analyse the impact of the programme vis-à-vis the baseline data that is collected prior to the initiation of any watershed activity.

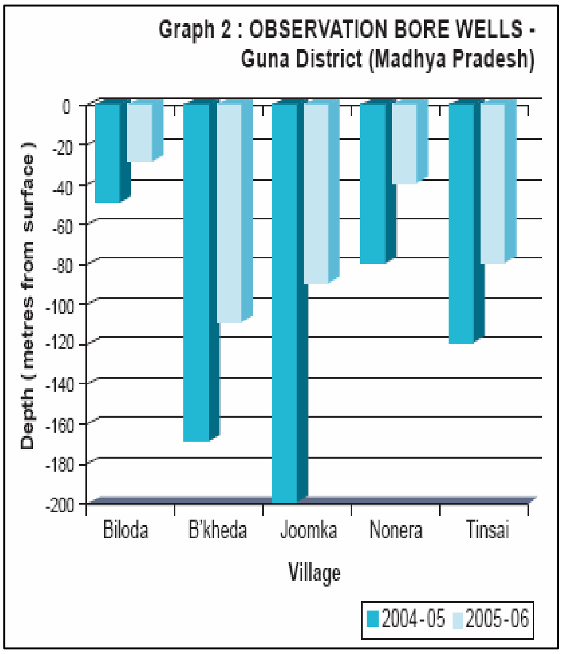
The main indicators that this MIS attempts to capture are :

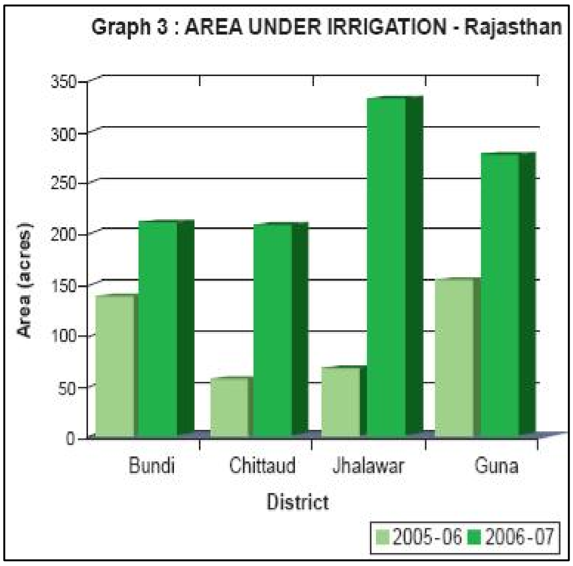
1. reduction in soil erosion
2. increase in water availability
3. changes in area under irrigation
4. cropping intensity and cropping pattern

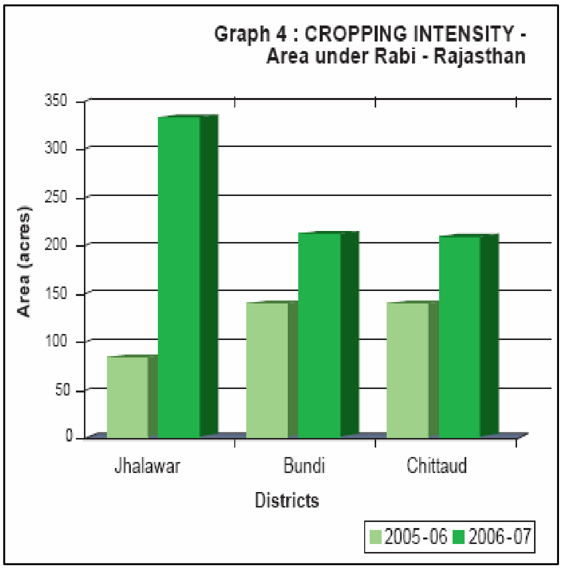
Since constraints of space do not permit the sharing of all the impact indicators, three of the main impact areas are illustrated below :

The first and most visible impact of effective watershed projects is the extent of ground water recharge. Regular readings of observation wells (both deep bores and open) capture data on the height of the water column. Graphs 1 & 2 clearly show that the projects have succeeded significantly with regard to this objective. Water is now available much closer to the surface in both types of wells, indicating effective recharge of ground water.









The second indicator tracks the changes in area under irrigation, which should increase due to increased availability of water. Graph 3 gives clear evidence of this – in most of the districts, area under irrigation has more than doubled. Moreover, the number of times the standing crops are irrigated has gone up significantly while the amount spent on irrigation has declined steeply. Both have positive impacts on farm economics – the former through increased yields and the latter through decreased costs.

Finally, an improvement in the moisture regime must lead to changes in cropping intensity. In the first instance, this is revealed by a shift from a single crop to a double cropping regime. Graph 4 shows a 183% increase in the area under the Rabi crop (the second crop after the monsoon crop).

Such a change is important for the economy of the village – the farmers now earn incomes from two crops instead of one, while on-farm employment for the landless increases because more area is under cultivation for a longer time. This results in a sharp fall in rural out-migration of poor families since they can now find gainful employment within the village.

Case Study

Mahadevji Gujjar, President, Water User Association Salawaliya Village, Bundi District, Rajasthan "Agriculture, dairy and seasonal labor work in the nearby areas are the main means of livelihood in my village, Salawaliya. It is a dry area with an average annual rainfall of 74 cm. Wells are the major source of irrigation. In June 2005 our village had only one farm pond in need of renovation, a defunct lift irrigation system and one anicut (check dam) on Blandi River, which also provided irrigation to Sahaspuriya village downstream. With ITC's help, we formed a water user group and look at us now.

* Rabi crops are sown between October & February and harvested by June.

** Kharif crops are sown between April & July and harvested by October.

Within a year we have constructed 5 water harvesting structures. We felt that a check dam across the Blandi would be really useful to recharge our wells and store enough water to irrigate our Rabi * crops instead of letting it flow downstream as it used to. Then the whole village got together to map the natural drainage sites before finalising and constructing the Kharad Guan Anicut. Each household contributed 25 kgs of wheat and 4 days of Shramdaan (labour). There is a smile on everyone's face this monsoon – the anicut and wells are brimming with water, the ground water has been recharged and we know that there is enough water for us to irrigate our Kharif ** crops during the long dry spell.

Our water user group is very active – together we decide on the equitable distribution of water after taking stock of the amount in storage. We also collect water cess from villagers for irrigation and also from well owners downstream on the basis of the livestock holding of each household. The cess is used for the maintenance of our precious structures and developmental work in the village."

ITC as a whole continued to remain water positive for the fourth consecutive year thanks to a three-fold strategy:

- Conservation, audits and benchmarking within the units to achieve the lowest specific water consumption.
- Zero waste water discharge from the units through treatment and recycling of all wastewater.
- Creating a positive footprint through rainwater harvesting both in the Company's units and through its integrated watershed programme.

All units in MKL

WATER BALANCE AT ITC	2002-03	2003-04	2004-05	2005-06
Freshwater intake	24.10	22.48	24.98	25.58
Treated effluents discharged	14.64	14.04	19.55	20.96
Net water consumption	9.49	8.44	5.43	4.62
RWH potential created within ITC units*	0.24	0.39	0.34	0.61
RWH potential created through watershed projects*	12.50	15.67	16.52	18.99
Total RWH potential created*	12.74	16.06	16.86	19.60

* Cumulative till year to date

The Uniqueness of ITC's Model

The fact that rapid economic growth is the only realistic means to alleviate extreme poverty and the fact that most economic activities depend on products and services provided by ecosystems, necessitates the ushering of a new business paradigm which enables rapid economic growth without compromising the capacity of ecosystems to sustain, nurture and fuel economic development and human well-being. ITC's integrated strategy places equal emphasis on the rehabilitation and the optimisation of use of resources. This strategy focuses on goals and targets which complement the Indian Government's initiatives to secure a 'new deal' for rural India, embodied in the 'Bharat Nirman' programme which is aligned to the UN Millennium Development Goals.

1. *Scale and Replicability*: ITC's model has an in-built potential for scalability because it converges social and business goals. Through its rural partnerships, the Company touches the lives of nearly 4 million villagers across India and the expanse of its diverse value chains enables its business models to play a significant role in the creation of wealth in rural India. Its watershed initiatives, which are the core of its model, strengthen the village economy and demonstrate direct and tangible economic gains for rural communities who are the key participants in promoting better water management regimes.

2. *Bottom-up Planning & Grassroots Implementation*: Grassroots capacity building is at the heart of all ITC's developmental models. Water management initiatives are tailored to individual community needs through site-specific, community-based micro-planning processes with professional support from a dedicated project management team. The full spectrum of the activity – from planning to actual implementation, record keeping, wage payment, procurement of raw materials and cash handling – is carried out by the community. The project team acts as a

facilitator, providing technical support, training, research and dissemination of best practices.

Depending on the socio-economic conditions of the community, their contributions vary from 20% to 70% of the total cost of these community managed projects generating a high level of ownership leading to more efficient use of resources and the realisation of the need for conservation.

3. *Sustainability – a Prime Focus* : The creation of community-based organisations at the village level that are empowered to manage the projects independently addresses the challenge of their long-term sustainability. ITC's models have demonstrated that it is eminently possible to create a Village Development Fund (VDF) raised exclusively through water user charges levied and regulated by water user groups. These VDFs are used for the repair and maintenance of existing structures, and serve as a corpus for investing in new ones as well as for building other collective assets without the community having to depend on external agencies.

4. *Integrated Approach – Watershed Plus*: The traditional approach to watershed management focuses primarily on the physical implementation of soil and moisture conservation initiatives and activities. ITC's watershed development model goes the extra mile by focusing on Watershed Plus activities. It is an integrated package of bio-mechanical measures which include improved agricultural practices like composting, promotion of market-linked high value crops and efficient irrigation devices as well as other crucial interventions like livestock upgradation that enable the creation of sustainable off-farm livelihood sources.

   Indian farmers suffer from poor market linkages. ITC provides the power of rural connectivity to millions of farmers in the remotest villages through its e-Choupal initiative. This digital network bridges the information gap between farmers and the market by delivering real-time information and customized knowledge to improve the farmer's decision-making ability, thereby securing better quality, productivity, higher prices and enhancing his competitiveness in the global market.

5. *Public-Private-Community Partnership:*: ITC recognizes the importance of reaching a critical scale to make an effective impact, which is only possible through multi-stakeholder partnerships – including communities, local bodies, NGOs, professional agencies, corporates and the Government at all levels. A key factor in the success of the Company's integrated watershed development model is that it has been able to create productive partnerships by involving stakeholders at all stages of the projects. By enabling communities to be aware of and tap government development measures, the services of different Government line departments – Forestry, Agriculture, *Panchayat* Samitis (village-level government agencies) etc. – are channelised through community-based organisations. ITC has already pioneered a public- private model for wasteland development with the Government of Andhra Pradesh and is in the process of finalising a collaborative model for the implementation of integrated watershed development with other State Governments based on the success of its watershed programme.

Conclusion

Currently, agriculture and manufacturing account for 19% and 27% of India's GDP. The country aims to achieve over 10% GDP growth and to become a global manufacturing hub. While the country's National Water Policy provides a framework for coordinated water development activities, it is not supported by legislation. With India already categorized as water-stressed, this has serious implications for the country's water resources.

As one of India's largest corporates, ITC is in a unique position of being able to address the urgent task of sustainable water resources management. The Company is committed to not just minimizing its environmental impact, but to creating a positive environmental footprint and to performance beyond compliance. ITC's rainwater harvesting projects within its operating units together with its integrated watershed development programme have resulted in ITC being 'water positive' for the past four years.

ROLE OF WOMEN IN GROUND WATER CONSERVATION, SUSTAINABLE AND EQUITABLE USE

D. Janaki*

Water is the elixir of life. It is a known fact that water as a resource is not limitless and perennial. Water management and conservation of water constitutes one of the major areas of human interventions *full of challenges in the 21st century*.

Since the ancient age, women have been largely confined to activities concerning the household sphere such as giving birth to children, child care, cooking, nursing of ailing members of the family, assisting male members of the family in farming and production of goods in the household cottage industries, looking after proper cleanliness and sanitation of the house etc., As the second World Water Forum in the Hague (2000) it was recognized that in addition to being prime users of "domestic water", women used water in their key role in food production and that women and children are most vulnerable to water related disasters. The forum concluded that women's involvement would improve governance. Since women bear the brunt of the burden of poor management, they could be empowered through greater and more effective participation.

The empowerment of women is necessary to ensure gender and social equality and would enable women to take control of their own lives, to challenge the oppressive aspects of social systems individually and collectively and to enter into relations with men on the basis of equality. These broad and ambitious goals are related to more instrumental aims of ensuring efficient water supplies. The impacts of improved water supplies can be translated into tangible benefits for women; better health, time freed up for other activities and more productive potential. All these outcomes can provide the basis for greater equality in their everyday lives. Moreover, a greater say improved skills in decision-making and in managing resources may strengthen Women's ability to contribute to the transformation of societal inequalities.

Women have long been a focus in the domestic water sub sector, their central place based primarily on the idea of their "natural" role as household managers. For many years women have been identified as the main drawers of water; the primary promoters of hygiene behaviour among children and those most likely to benefit from improved water supplies in terms of alleviation of the burden of their domestic tasks. In the 1980s, much of the work associated with the international Drinking Water Supply and Sanitation Decade emphasized the water sector as a "women's sector" based on women's responsibility and the household division of labour. Much work identified multiple public and private roles for women in the management of domestic water, detailed the complexity of interaction around women's water use and highlighted the need for planning within a social context. Women have played roles in this sector, as village health workers, hygiene educators and local level latrine builders and water-supply technicians. However, the domestic water subsector has been slow in expanding its focus to women's productive concerns and to men's involvement in health and hygiene aspects of water and sanitation. A concern with gender perspectives has only recently been incorporated into plans for saving and conserving water. The emphasis has been on Women water users as farmers and on the outputs in terms of increased agricultural production. Studies have shown the strategies that women farmers have to employ to secure their irrigation needs, such as stealing water, taking water at night, and using male relatives as champions to

*Vice Chancellor, Mother Teresa Women's University, Kodaikanal, Tamil Nadu, India.

secure access to such water. Access to irrigated water is also heavily dependent on land rights (in which women often have disadvantageous positions) and on control over labour. Many irrigated fields are worked by women and children, and yet it is the men who dominate decision-making about the distribution of water and often market the proceeds and determine the use of the cash generated.

It is a common sight in rural India that shows women carrying water after taking bath to their home, from village tank or riverbank. Rarely one notices men carrying water. It is also true that on the bank of river or tank or pond that real village politics takes place as information from one family to other passes ultimately to blow up into a large proportion often adding to it various imaginary stories.

In urban slums the women stand in linear or curbed lines to fetch water from only water tap in the slum during the specific hours of supply. One may notice news paper reports with photographs during draught situation to see women eagerly waiting for getting a few drops of water from water sources either through the tanker arranged by Government or from wells or ponds tending to dry. In flats, bungalows or houses of urban areas where water supply is ensured through pipeline such situation is usually absent but at the time of crisis it is certain that women only take care to see that the buckets are kept filled.

At the International Conference on Freshwater in Bonn in 2001, the policy statement emphasized the need for a gendered approach involving both men and women, while also suggesting that in order to achieve this, women's roles in water-related areas needed strengthening. Further emphasis on equality (including gender equality) was given in the statement of the Third World Water Forum in Kyoto in 2003. In the quest for safe, clean water for all , many governments face a crisis of governance and need an integrated water resources managed approach with transparent and participatory approaches that address ecological and human needs. The Ministerial Declaration stated that, "In managing water we should ensure good governance with a stronger focus on household and neighborhood community-based approaches by addressing equity in sharing benefits, with due regard to pro-poor and gender perspectives in water polices. We should further promote the participation of all stakeholders and ensure transparency and accountability in all actions". (Women 2000 and beyond 2005, P3)

Other international meetings and policy statements, concerned with a broad spectrum of goals from poverty eradication to environmental sustainability, have been concerned with both water and gender equality. The Millennium Development Goals adopted at the Millennium Summit at the United Nations in New York in 2000 included goals to "promote gender equality and empower women" and to "ensure environment sustainability". One of the targets for the goal on ensuring environmental sustainability is to "Halve by 2015 the proportion of people without sustainable access to safe drinking water and basic sanitation". At the World Summit on Sustainable Development in Johannesburg(2002) commitments were made to promote Women's empowerment and emancipation and incorporate gender equality in all the activities specified in Agenda 21 of the Millennium Development Goals and the Plan of Implementation of the Summit.

It has become increasingly accepted that women should play an important role in water management and its conservation and that this role could be enhanced through the strategy of gender mainstreaming Gender mainstreaming is "the process of assessing the implications for women and men of any planned action, including legislation, policies or programmes, in all areas and at all levels. It is a strategy for making women's as well as men's concerns and experiences an integral dimension of the design, implementation, monitoring and evaluation of policies and programmes in all spheres so that women and men benefit equality". (Women 2000 and beyond 2005, P4)

In water policy, gender mainstreaming is justified for reasons of efficiency and effectiveness; a gender sensitive approach helps to ensure that supplies are provided and managed more sustainability. It is also argued that gender mainstreaming helps to empower women and so further the broader goals of equality within society, contributing to poverty alleviation and social inclusion.

On the eve of the World Water Day, the United Nations general secretary, Mr.Kofi Annan predicted that fierce water disputes among the nations could be the seed of future conflicts. Till date, deaths due to water-borne diseases outnumber the deaths that occur during wars. It is estimated that more than 1.1 billion people in the world lack access to safe drinking water and 2.5 billion people do not have proper sanitation. According to UN predictions, nearly two thirds of the population will soon meet with the same fate. The looming crisis that will overshadow the world is mainly due to continued human mismanagement of water, population growth and changing weather patterns, UN organizations said recently. The average person needs a minimum of 1.3 gallons (five liters) of water per day to survive in a moderate climate at average activity level, according to UN figures. The minimum amount of water needed for drinking, cooking, bathing and sanitation is 13 gallons (50 liters). In the last century demand for water increased six fold, more than double the rate of growth of human population, while pollution and over-extraction in many regions of the world has reduced the ability of supplies to meet demand. The availability of fresh water is just three percent and access to fresh water is less than a quarter of one percent. So unless all countries in the world sit together and chalk out a strategy for the sustainable use of water, it is going to be a very serious concern. The United Nations General Assembly has proclaimed 2003 to be the International Year of Freshwater. Hence it is left to the countries of the world to decide what has to be done.

Women are not only recognized as a primordial human resource through the symbolization of nature as cultural practice. They are also associated with the use of water for the prosperity of the farmer community and also celebrating the fertility of women. Women are linked with the reproduction of natural capacity of the earth are a significant medium of exchange as reflected in the water rituals. To symbolize the beginning of farming activity on the occasion of the first flush (flood) of the water for irrigation, women are involved. This involvement of women is done through an institutionalized ritual embodied in the Hindu religious mythical framework as an empirical tradition. The form and shape of this ritual varies as per vision and imagination of the people over a period of time and in different regions. But it is having a cardinal symbolism of associating fresh water with the fertility of the earth and women. The prosperity of the society through the increased reproduction of the grain from the fields and the prosperity of the family is usably associated with the reproductive symbolism of women in the family.

It is self-evident that water scarcity is one of the greatest threats to the world within the next quarter of the century, according to the draft report by the World Commission on Water. The report states that the total demand for water for agriculture, industry, and human consumption will be between 4,279 and 5,235 Cu Kms by 2025, a 40 percent increase above 1995 levels. One of the main problems relating to water resources in India seems to be to have inadequate water management principles and indiscriminate water use and indifference to the significant role by women. It is needless to say that the women of 15-35 years are the principle collectors of water in India household. They collect atleast 192liters of water per day for each average household of seven members (UNICEF - 1990). Similarly in the field of irrigation, women are involved in the irrigation activities relating to water resources. In their role as providers of water, women suffer the impact of depleting water resources. The amount of time women spend in carrying water varies across regions and can be a high as four hours a day(GOI,1998 a).Whatever the distance it is covered by foot, it is carried by women alone (UNICEF 1991) and water scarcity affects women more harshly than it does men.

But in the management of water and its conservation in terms of timing and other dimensions, the involvement of women is indirect and restricted. It shows that the legal norms in determining the title of the land to male members of the society appear to be major factor in restricting the women in water management and its conservation. Despite women's traditional knowledge in water collection and management, they are perceived as beneficiaries of water projects rather than partners in planning or managing them. With increasing recognition of the need to involve them, the new water supply system, both for the acceptance of the system and for giving women a role in the management of resource, several initiatives have recently been undertaken. Examples are Kerala Water Authority and the Integrated Sanitation, Water Guinea worm Control and Community Health project. (SWAC) launched by the Government of Rajasthan, Village Action Committee in Andhra Pradesh Village Water Committee in Uttar Pradesh in India and the current practice of transfer of Irrigation Management to the farmers.

Be it drinking water or irrigation or agriculture, they are merely representing rather than involving in the decision-making. The decisions made by the male members are always endorsed by the women themselves. They are so conditioned that they have their mainstreaming role in ritual practice and do not see similar mainstreaming role for themselves either in the form of leadership or as decision maker when water has to be managed.

On the other hand the collection of the water and storage and maintenance or water for drinking is done by women particularly those belonging to the lowest economic status. These women have domestic work, wage work and also water collection work. But they do not have the role in the management of water security.

There is another example of a development programme that neglects women i.e. In a remote Ethopian village, a development project was designed to dig a well , as women had to walk 5 Km for water. This development project involved the men of the village to dig the well and train the men to maintain it. When the very same well went into disrepair it was not restricted for use. The development mission discovered that it is a culture of Ethopian and also it is an important social function for the women to dig and maintain the water supply. In both cases of Ethiopia village and in Chennai city, it apparently brings forth that women have distinct role in water related activity. The Indian case study of the water ritual practice also gives a predominant role for women. What is to be discovered is the oppression which women are made to suffer by saying that it is cultural practice. This has to be analyzed from the feminist perspectives and they should be used for water related management practices.

Eco feminism is the one, which analyses environmental problems as a critique of patriarchy to liberate both women and nature. Feminists are interests in knowing why women are treated as inferior to men. On the other hand environmentalists are interested in explaining why nature is treated as inferior to culture. Nature is largely being seen as feminine while women have been identified very close to nature. This association i.e. Women and nature is nothing but a double oppression entrapping and devaluing and thereby women are apparently honoured through rituals for common interest of the society, while women are neglected as far as individual interest of women is concerned. i.e. Procuring water. Eco-feminism is a social movement which seeks to explain away the oppression by arguing, that environmentalism and feminism cannot be separated. This phrase of a “Mother Earth” and “Fertile River” are all nothing but a popular way of symbolizing women only to mislead, the real views on women with blind-spot. Particularly when it concerns women who suffer for collection of water are the entire one who belongs to same socio-economic class. Thus it leads to a theorization of gender, class and nature.

As far as movement are concerned, in the last two decades the two movements namely Women’s movement and Ecology movement got mutually reinforced only to assert that these development practices need not be confined to male biased models of domination as Rosemary Ruether wrote in 1975 in her book, New Woman/New Earth that the need for radical reshaping of the basic socio economic relations and the underlying value of this industrial society is only through the solution of ecological crisis where women are subjugated.

In the last three decades, many feminists’ particularly ecological feminists are asserting the important connection among feminism, ecology and environmental philosophy. They are called eco-feminists who elucidate women and nature connection. There is a sequential relationship among gender, class and culture and there is a convergence, of the western and non-western tradition of eco-feminism on the need to mainstream women in the management of natural resources a new policy to integrate Women and Development in mid 1970’s has developed a strategy of what is called Women in Development approaches. Parallel to these W.I.D., women researches and development agencies have developed a new concept by highlighting that the Mainstream development will be futile without the Mainstreaming of Women.

Mainstreaming women is a new argument and Rethinking gender and development. It proposes to bring women from the margin in to the centre of the main development programmes and of the institution that deal with economy.

If gender is constructed without essentialising it as a core element in the development process it is to dismantle the invisibility of women, they will not be effective enough to provide justice with alternative truth. In the need for embedding every action in structures of power, the development theory cannot be complete without getting gender embedded in the Structures of Power. Mainstreaming women through ritual power structure should be extended to the structures of organizational and managerial power. The role of eco-feminism is to lead the women in the water management practices. The current effort of mainstreaming women and development will be inadequate if it is done without recognizing significant Women Nature connection. The strategy of mainstreaming women in the development process will be benefited by the contribution from the socialistic eco feminism which promotes partnership ethic to keep both men and women as equal partners in dealing with nature. So there is a scope for tailoring the water-ritual practices within the development fabric of water management practice.

Ground Water

Ground Water is a valuable resource that is withdrawn in all parts of the country for a variety of uses. Groundwater is especially important in a selected number of locations for a specific number of water users, including self-supplies domestic, commercial and livestock users in particular. As this resource becomes more contaminated and scarcer, demand for high-quality water will continue to grow making groundwater even more valuable and protection more important.

Water conservation can be defined as, 1) any beneficial reduction in water loss, waste, or use; 2) a reduction in water use accomplished by implementation of water conservation or water efficiency measures; or, 3) improved water management practices that reduce or enhance the beneficial use or water. A water conservation measure is an action, behavioural change, device, technology, or improved design or process implemented to reduce water loss, waste, or use. Water efficiency is a tool of water conservation. That results in more efficient water use and thus reduces water demand. The value and cost-effectiveness of a water efficiency measure must be evaluated in relation to its effects on the use and cost of other natural resources (e.g. energy or chemicals).

Water conservation may have different meanings for different people. It may remind us of the possibility of collecting rainwater in small tanks for domestic use, or constructing dams and reservoirs; of recharging groundwater tables, or using lower quality water whenever possible in order to save better water. Water conservation encompasses all this. It involves reducing the demand for water by fostering water conservation habits, stopping wasteful uses, decreasing peak consumption and charging for water at the appropriate rates. It also means taking advantage of technological developments and improved management techniques; coordinating water resource planning and management with land-use planning and economic and social planning; and establishing new or updated standards and regulations. In short, water conservation means optimal water use.

Artificial Recharge is the process by which the ground water reservoir is augmented at a rate exceeding that under natural conditions of replenishment. Increasing pace of ground water development to meet the growing demands of water in agriculture, industrial and domestic sectors, has brought problems of over-exploitation of the resource, continuously declining water levels, seawater ingress in coastal areas & ground water pollution in different parts of the country. The falling ground water levels in various parts of the country have threatened the sustainability of ground water resource, as water levels have gone deep beyond the economic lifts of pumping. The speedy & uncontrolled development of ground water resources has resulted into increase in over-exploited and critical/dark blocks from 253 to 1065 between 1985 and 2004.

Apart from groundwater exploration work, geophysical surveys have also been conducted for other purposes like artificial groundwater recharge, watershed development studies and pollution studies. We know that water is the basic need for most of activities in a watershed and today groundwater is being considered as much more valuable resource than it was in the past. Hence, groundwater exploration, exploitation and management are coming to merit the geo-scientific techniques. Due to increased demand and over-exploitation of groundwater in watershed area, the search for potential groundwater zones and its augmentation through various artificial recharge structure is imperative. The basic considerations for understanding the sub-surface behavior of a watershed are characteristics of soils, overburden thickness, direction of groundwater flow, sub-surface basement topography, nature of watershed fills, presence of fracture/micro-fracture in the watershed, geology and geological structures. These basic considerations can be easily obtained through geophysical techniques for selecting areas, zones and locations for the desired sustainable development of the watershed.

As natural replenishment of ground water reservoir is slow and is unable to keep pace with the excessive continued exploitation of ground water resources in various parts of the country there is an urgent need to augment the natural supply of ground water through artificial recharge of ground water. The artificial recharge techniques aim at increasing the recharge period in the post-monsoon season for about 3 more months by providing additional recharge. This results in providing sustainability to ground water development during the lean season.

On the basis of experience gained through implementation of the Central Sector Scheme on Studies on Artificial Recharge to Ground water during the VIII and IX plan periods, wherein more than 1000 artificial recharge were constructed, the Central Ground Water Board has prepared a technical report on the potentiality of artificial recharge to ground water in different hydrogeological set-ups of the country based on the twin requirements of availability of non-committed runoff and suitable aquifer for storage. However, there is a need to prioritize the areas where schemes need to be implemented as a first priority to ameliorate the water scarcity problems. It is proposed that artificial recharge to ground water should be taken up in the 1065 over-exploited/critical areas on topmost priority. Second priority should be accorded to 546 semi-critical areas where the stage of development is significant. The members may like to express their views on prioritization of areas to be taken up for artificial recharge to ground water. The technical report for artificial recharge is prepared on the basis of hydrogeological parameters and hydrological database available for each State.

A gender approach to water conservation:

A gender approach to water resources management, for example, strives for a balanced division between men and women in the following areas; access to information; physical work; contributions in time and cash; decision making; and access to and control of resources and benefits. Such as approach would take into account;

- The difference between women’s and men’s interests, even within the same household, how these overlap or conflict and how they are negotiated;
- The conventions and hierarchies that determine men’s and women's position in the family, community and society at large, which often lead to the subordination of women;
- The differences among women and men based on age, wealth, ethnicity and others factors;
- The way gender roles and relations change as a result of social economic and technology trends.

These proposition outlined above support the adoption of a gender approach to water resources management and the need for stringent measures to conserve water for the future.

So far there has been little emphasis on gender perspectives in sub sectors devoted to “Water for nature” although it is well known that men and women may have differing interests in drought mitigation, flood protection, and mangrove, forest and fisheries management. For example, in fishing communities men might fish in offshore or major inland water bodies, while women fish close to shore and the fish-processing activities undertaken by women may be under-recognized. In the 1980s and 1990s some “ecofeminists” claimed that women's gender-specific interests coincide with environmental conservation and that their instinctive understandings of nature make them “natural” environmental managers. However, such views are problematic in gender-equality terms, as they mirror ideas that women are the “natural” managers of domestic water, and that therefore the burden of responsibility for such management (and its outcomes) should fall upon them. This simplified approach has been replaced by a more nuanced understanding that men and women do have different priorities and perceptions regarding natural resources and that these will shape their involvement in water management and conservation.

In areas of environmental degradation and high male labour migration, for examples, women assume the prime responsibility for food production and so changes to land access, water supplies and labour availability may disproportionately affect them. Poor rural families tend to depend heavily on common property resources such as water sources, grazing lands and forests for food, fuel and fodder. Entitlement and access to natural resources is often shaped by gender and other power relations. A gender perspective could help to analyze how land rights, rights of use and command over labour help to define inclusion and exclusion from such resources, particularly in times of environmental stress and natural disaster. For example, in Bangladesh people cope with floods by emergency selling of assets. Women have been found to be at greater risk of long-term flood -related economic loss than men, because their assets such as jewellery and household utensils are devalued in such circumstances and command lower prices than men’s assets such as farm implements and animals.

A gender perspective also facilitates looking beyond uses of water and other resources to the societal relations that place people in positions of advantage and disadvantage. Recent work has used social and gender analysis techniques to move beyond the identification of women’s and men’s separate vulnerabilities towards understanding how building on livelihood interdependencies within communities can strengthen their resilience in the face of natural disasters.

The current concern with user participation in the better governance of water includes the desirability of including more women in water management institutions. To this end many policies and project guidelines suggest that women should be particularly targeted as members of water management committees and should play active roles as chairpersons and treasures. The arguments for women’s involvement are numerous. Women's daily concerns with fetching and using water are thought to make them both knowledgeable about water sources and interested in their reliability, making them well-motivated managers in areas where there in high male labour migration, women may provide the majority of regularly available community members. So ensuring continuity and consistency of management. It is argued that women can also best represent the views and interests of other women and ensure that water management is not dominated by men’s priorities alone. In addition, generalizations about women’s abilities and characteristics are often used in support of their greater involvement women are more trustworthy, community minded and altruistic than men.(Women 200 and beyond,P.13)

The recognition of women’s potentials as mangers and the importance of their involvement in public decision-making processes are welcome and long overdue.

The example in Ukraine illustrates how Women's involvement in campaigning for better services can secure impressive results for all community members. However, gender approaches are often implemented in a routinized and tokenistic way that does little to further goals of equality and effectiveness. A gender analysis of participation, decision-making processes and the workings of institutions helps us to understand why many efforts in the past have led to women's partial involvement and why outcomes do not necessarily favour them.

How can awareness of the complexity of issues around gender and water be translated into practical actions with tangible results for both efficiency and gender equality? Gender mainstreaming strategies require changes in institutions to facilitate incorporation gender sensitivity at all levels and in all activities. Putting commitments into practice in the water sector is important. Although there is growing recognition of the importance of social components of interventions, technical and economic aspects continue to dominate and are often perceived as quicker and simpler to implement. It cannot be taken for granted that the existence of a gender-equality policy is sufficient to ensure women's full participation in water programmes, or that gender considerations are always taken into account. Generally speaking there is a significant gap between policy definition and implementation, linked to the fact that gender analysis is still not a systematic and integral part of the majority of water interventions.

In may case, gender policy documents tend to be vague and consists of catch-all phrase that offer little concrete guidance at the implementation stage. This may be exacerbated by gender specialists whose advice is couched in general terms rather than concrete guidance for action. Phrase such as "a gender perspective should be adopted" or "all gender-related issues should be specified leave staff at a loss as to what this actually means and how it can be put into practice. This is made worse by project documentation that continues to talk in gender-neutral terms referring to the "community" the "users" and the "consumers" rather than referring to people in more socially specific terms , such as "poor women", "wealthy women" or "local male leaders".

Mechanisms are needed to facilitate the dissemination and implementation of the gender policy through out relevant organizations at both the central level and in the field. These include policy statements and budgetary commitments, procedures relating to institutional learning, responsibility and accountability, planning and evaluation methodologies, personnel policy and training and data collection. Additionally evidence suggests that these framework that specifically recognizes human rights and where there are strong agencies advocating for the uptake of these rights. An important instrument is the Convention on the Elimination of All Forms of Discrimination against Women.

Gender sensitive approaches to water recourses management are desirable for archiving efficiency, social equity and gender-equality goals. Targets, such as those in the Millennium Development Goals relating to water, are unlikely to be achieved unless gender perspectives are integrated into planning and implementation activities. Instrumental approaches to ensuring more reliable, sustainable and well-managed water supplies are essential to achieving access to water for all, and for ensuring the maintenance of water in the interests of ecological balance and the needs of future generations. However, social and economic targets(such as eliminating poverty, furthering empowerment of marginalized groups, supporting the resilience of the vulnerable and ensuring resources are appropriately managed by those who use them)will only be achieved by a wider focus on social and power approaches therefore means rethinking water development in a number of ways.

Firstly, it is critical to recognize the need for intersectional cooperation. People's livelihoods are not divided into sub sectors on the management of water for a different uses is unlikely to yield results. A gender -sensitive approach helps to overcome some of the artificial sub-sectoral divisions in water as it involves looking at women's and men's lives as a whole and how they are shaped through gender norms and practices.

Secondly, gender sensitivity necessitates a flexible learning approach to development interventions. Just as natural conditions and the uses of water vary from place to place, so gender expectation and norms differ according to context. Blueprint approaches to project planning and management cannot reflect this, so development agencies need to pay attention to training and capacity building which allows for a reflective and flexible approach to water resources management at the local level. Gender relations can and do change over time, and, by adopting participatory learning approaches, it is possible for agencies to support and facilitate such changes in progressive ways.

Thirdly, gender relations also impact development institutions, which need to pay attention to the way that such relations impact on the functioning of their own work, as well as on water resources management at the local level. This involves consideration of the type of data collected, the gender balance of staff and the need for gender-awareness training within an organization.

Frame works for gender analysis of water resources management that encompass issues of social and gender relationships as well as infrastructural provision are required to track both collective and individual actions and recognize both the separateness and interdependencies of women's and men's interests. Such an approach is unlikely to be achieved through the use of checklists alone, and gender analysis cannot be achieved in a one-off event. Rather it requires a re-thinking of the way in which development accommodates diversity, complexity and change, while retaining overall goals of an equitable and dignified life for all.

Women empowerment is a global issue. One of the millennium development goals of the United Nations is to "promote gender equality and women's empowerment". The stated goals is to eradicate poverty and hunger achieve universal primary education, reduce child mortality, fight against fatal diseases and ensure environmental sustainability. However these goals can be realized, subject to one of the natural non-replenishable sources that is fast becoming a scarce commodity-which is water. India is a land of a mighty network of various water bodies ,however poor water management and rapid pollution of these water bodies has resulted in a crisis that threatens to further worsen the health prospects of the Indian women. Due to various socio-cultural and ritualistic practices, Indian women are closely associated with water and are rated as the highest consumers of water though the bulk of water consumed varies from region to region. Indian households are totally dependent on their womenfolk for their water needs, particularly in rural India. As managers and custodians of their homes, these women in turn depend on water sources for their sustained livelihood. A massive pollution of these water bodies poses a serious threat as two-thirds of the illness in India is related to water-borne diseases.

Women access to water and their role in management are shaped by social relations and structure relations of family and marriage, caste and class. Women's biological functions like child health, menstruation, menopause all require clean water for health sanitation. Women's care and responsibilities are often increased by water related diseases thus intensifying their labour, reducing the amount of water they can collect and limiting the time they can spend engaging in community action. Water-related diseases affects the entire household capabilities and is increasingly constraining women's active participation in water resources, use and management. A gender analysis helps to identify ways in which health impacts of water resources affect women and men, girls and boys differently. Another gender specific disadvantage is the health impact of water work on women. Improved sanitation is critically linked to achieving the health benefits of clean water supplies.

For the ordinary rural women living a minimalist existence there can be no technical solutions. There is the basis sanitation and hygiene education which can be imparted together with consciousness raising of these women to methods of ground water conservation through public awareness campaigns, street plays and sharing of experiences in securing clean water. In India, there is a heavy dependence on the monsoon. If the rain fails and when water supply is not properly ensured in the planning process, women and only womenfolk suffer. In Indian villages, the water sources are tanks and ponds, rivers, wells and tube wells besides natural springs. Water supply through pipelines is rare except in the villages close to organized urban area. There is an acute shortage of water when there is a planning failure or if a river changes its course or a spring dries up or if water table falls due to various reasons. In such situations women have to travel far to fetch water. It becomes an additional burden on them together with their to usual duty of household's chores, tending children and involving in a part of agricultural operations. In an essentially male dominated society, planning also is done according to convenience of male members neglecting women. Thus resourcing water and its conservation are generally considered a second priority.

Recent policy initiatives reveal that there is a high level of "willingness to pay" for improved water supplies, often expressed by women indicate a total commitment to sustainable use and management of water. The ergonomics of water carried on the head is shown to have detrimental effects or the development and health of the spine leading to deformities, arthritic disease and injury.

While women may generally bear the burden of inadequate water supplies and water related work, there may be particular vulnerabilities related to men's roles. A pervasive health analysis of both men and women will reveal that women are placed at a greater risk in catching infections and communicable water bone diseases when compared to men. Hence there is the need for essentialzing women's roles, so that their marginalization in areas crucial to them can be eliminated. In India, the formation of the women into self-help groups is a great success story where women of the villages come together in a collective move to forge activities through strategic planning .With women placing themselves in vital areas of water management activities, they have become most vocal and articulate in supervising that the water needs of their particular villages are met. It is certain that day is not far off, when the Indian Women's search for clean water supply will end thus ensuring a healthy and disease free environment. And this can be achieved by solely one means which is through efficient ground water harvesting.

Women are water providers and principle collectors since domestic duties fall almost entirely on them, disappearing water sources have meant new burdens and new drudgery for them. Water scarcity implies longer walking for women for collecting water and implies more work and less survival options.

People's participation and social acceptance is essential for popularizing artificial recharge to ground water. The strategies for creating awareness, education and capacity building should focus on the following.

- Information on artificial recharge to ground water and best water management is gathered and disseminated among departments, agencies and stake holders.
- Facilitating linkages between research institutions and field agencies for development of appropriate cost-effective technologies, field demonstration and transfer to stake holders.
- Visits to be organized for water harvesting women functionaries and other women Self Help Group members to other villages for exposure to best practices for their motivation.
- Conventions to be organized for different stakeholders of water harvesting at various levels (village/mandal/division/districts).
- Implementation of demonstrative projects on artificial recharge to ground water in Government offices, Agricultural Farms Educational and Research Institute, for dissemination of technology by example.
- Local bodies like Municipalities, *Gram Panchayats, Mandal Parishads* to be involved in the entire programme for ensuring better results.
- Girl Students to be sensitized by including water harvesting, conservation and management as part of the curriculum.
- Greater participation of women in water harvesting capacity building programs needs to be facilitated through deliberate campaign, publicity, incentives, etc. to overcome the traditional biases of a male bastion.

Secondly, gender issues in this need to be explicitly addressed through training and awareness. A categorical inclusion of women in stakeholder analysis, women's viewpoint on priorities of water harvesting and women's role in harvesting and its maintenance from the grass root to the professional level has to be promoted at the stage of capacity building.

a) Dissemination of best information on artificial recharge and water management among departments, agencies and stake holders.
b) Importance / role of Mass awareness /capacity building.
c) Training/Conventions to be organized for different stakeholders of water harvesting at various levels (village/mandal/division/districts).
d) Involvement of local bodies like Municipalities, Gram Panchayats, Mandal Parishads in the entire programme for ensuring better results.
e) Greater participation of women in water harvesting capacity building programs through deliberate campaign, publicity, incentives, etc. to overcome the traditional biases of a male bastion.

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Theme: More Crop and Income per Drop of Water

ENHANCING WATER PRODUCTIVITY IN ARID ZONES OF RAJASTHAN

Pratap Narain*

India has 31.7 Million Hectares (m ha) hot arid region, of which 62% is in Western part of Rajasthan. The arid region is characterized by hostile climate, less than 450 mm erratic rainfall, extreme temperatures, high wind velocity and poor sandy terrain. The fragile arid eco-system supporting 107 human and 137 animals per square kilometer is overexploited and also subjected to frequent droughts and land degradation due to wind/ water erosion as well as salinity and alkalinity. Arid areas confront a permanent negative water balance (moisture index; -80 to –66.7%) (Krishnan, 1968) hence suffer from poor vegetative growth and productivity. Further, sandy soils of arid region are thirsty as well as hungry. These have very low moisture retention, organic matter and fertility, which limit their productivity. Increasing income and productivity per drop of water is the major issue in these water scarce regions.

About 19.7 m ha arid region is spread over 12 north western districts of Rajasthan under four agro-ecological zones. Nearly 10 per cent area of arid regions mostly in districts of Sriganganagar and Hanumangarh is irrigated through Indira Gandhi Canal. Remaining 90 per cent arid areas continue to depend upon rainfall, runoff water and deep limited underground water, which is often brackish. Pearl millet, cluster bean and khariff pulses are main rainy season crops and mustard, chickpea, barley, cumin, spices and isabgol are endemic crops grown in rabi season. Cropping alone is not a dependable proposition therefore, animals are main stay in arid region. Traditionally practiced animal based farming systems viz. agroforestry, silvipasture, arid horticulture with new innovations must find due place in enhancing income and productivity of arid areas on sustainable basis. Arid areas can be broadly divided into rainfed dry regions, well and tube well command regions and canal command areas.

Rainfed Regions

Rainwater harvesting & utilization: The rainfall in arid regions varies from less than 100 mm in extreme west of Jaisalmer to 450 mm on eastern desert margin. Depending upon the terrain, land surface and rainfall intensity, harvesting of rainwater, its storage and utilization primarily for drinking and now and then for agriculture has remained a very popular practice even in low rainfall regions. Potential for water conservation and harvesting against drought in Rajasthan has been elucidated (Narain et al. 2005). Potential of recharge of ground water through excess rainfall events/ flood event, though rare, has been computed.

Several kinds of rainwater harvesting system such as bawari, jhalra, talab, tanka, kund, nadi, khadin have been in vogue. Runoff harvesting and ground water recharge is now achieved through anicuts, subsurface barriers, ponds, infiltration wells and galleries also. Harvested water is precious therefore, often utilized for drinking, house hold and raising nursery etc. CAZRI has designed Tanka and Nadis of various capacities. These are maintained by individuals or communities. Unfortunately, some of these structures have been relegated after piped water supply to villages or *dhanis* has been provided.

For agricultural purpose, bigger dams, anicuts, talab, sar and khadins have been commonly used. Micro-irrigation techniques suggested in later part of this paper can be utilized with these storage structures to obtain high water use efficiency. Land and

*Vice-Chancellor, Rajasthan Agricultural University, Bikaner

water conservation, their management practices, choice of plants, crops and their varieties, systems of watering, mixed/ perennial vegetation based farming and integration of animals will go a long way in enhancing arid land income and productivity.

Prevention of wind erosion: Fury of wind erosion due to high wind velocities (up to even 35-40 km/h) from May to June is required to be reduced to prevent colossal drifting of sand, chocking of canals, reduce high evaporating demand and loss to infrastructure and communication. An extensive survey of shelter belts in Indira Gandhi canal and tube well command in Jaisalmer (Mertia et.al. 1907) has projected that if entire canal or tube well command area would have been covered by shelter belts in Rajasthan, additional income from crops and trees could have been generated to the tune of Rs. 7134 million in a span of 15 years. This could have reduced livestock migration and capacity to fight drought by multiple benefit accrued by shelter belts.

A three row shelter belt consisting of *P. juliflora* as outer rows, and *Albizzia lebbek* as central row reduced wind speed by 20% at 10 m (height) distances from shelter belt to 38-46% at 2 m distance during summers (Abrol and Venkteswarlu 1989). On an average, shelter belt reduced wind speed by 20-30%, wind erosion by 50%, and conserved moisture thereby increasing yield of pearl millet from 4.8 q/ha to 6.9q/ha with shelter belt plots. Wind breaks of *Acacia nilotica* and *Dalbergia sissoo* have been successfully established at Suratgarh farm. Shelter belt effectively reduce evaporative demand on leeward side thereby enhance productivity per unit of water use. Adverse effect of wind erosion can be reduced through sand dune stabilization by utilizing technology developed by CAZRI, Jodhpur.

Mixed/ Inter cropping: To minimize risk factors, mixed cropping of cereals, pulses and minor millets in varying proportions has been a common practice. A sole crop of pearl millet could yield as much as 2.3, 1.5 and 0.4 tonnes/ ha in good (<400 mm), normal (300-400 mm) and scanty (<250 mm) rainfall respectively. Pearl millet crop + green gram moth bean intercropping can produce a maximum of 5.0 tonnes/ha in normal rainfall years (Gupta et al 2000). Improved genotypes of pearlmillet MH-179, HHB-117 and moth bean (RMO40, CAZRI Moth-1, and Maru moth) and green gram (SLM 668) may perform still better. Fodder from pearl millet or pulses is an important component for sustaining animals in poor rainfall and drought years.

Alternate Land Use Systems: To combat drought in the arid region, which occurs in 36-40 yrs in a cycle of 100 year, people have deviced novel approaches of agroforestry, agrohorticulture, hostipastoral and silvipastoral practices, using native as well as exotic species. *Prosopis cineraria* is considered lifeline of deserts to provide protein rich fodder with positive effect on crop yields by enriching fertility and moderating harsh arid climate. *Hardwickis binnata*, *Colophospermum mopane*, *Acacia Senegal*, *Tecomella undulata*, *Ailanthus excelsa* and *Ziziphus mauritiana* have been integrated with crops and grasses to enhance total productivity. Such systems help integrating livestock with farming, which is crucial for sustainability in arid region.

Well / Tube Well Command

Ground water is very deep (>130 mbgl) in arid Rajasthan and also brackish which may be as high as 68% (Manchanda, 1989). Of these, 50% are saline sodic and poor in quality. However, well irrigation accounts for 70% irrigated area in Rajasthan and perhaps 90% in arid region. Indiscriminate installation of tube wells and power supply to agriculture has led over-exploitation of ground water from 48.3% in 1991 to 121.8% in 2001 (Narain & Amalkar, 2005). The number of over exploited blocks in 1990 were 44 which increased to 120 in 2001. Critical number of over-exploited blocks account for 70% area of the State (Mathur, 2006). Economizing on ground water use and enhancing productivity of per drop of water is the dire need in tube well command. Farmer has to totally shift to sprinkler or drip irrigation immediately. Efforts have to be made to recharge ground water through anicuts, storages, pondage, roof water harvesting etc. (Narain et al, 2005).

Canal Command

With availability of canal water cropping pattern of arid areas has drastically changed to wheat, rice, cotton, groundnut sugarcane, spices like cumin, chillies and vegetables. In order to obtain highest production, most of the crops have been over irrigated. The irrigation efficiency is low, non-ET losses are high and many a times water logging and salinity is developed. Seepage through canal network, poor on farm management, impervious hydrological barriers, lack of drainage etc. has resulted in rise in water table within 1 meter depth from 15-40 m deep before the start of project. Nearly 0.22 million ha area is considered potentially sensitive to water logging. About 24,152 ha. has water table within 1.5 m and 11592 ha has standing water and affected by water logging and salanization. On the contrast tail enders suffer for want of water. The canal command water has been obtained at huge investment hence optimal irrigation to achieve maximum production and extend irrigation to larger areas is absolutely necessary. Following strategy is required to prevent overuse of water.

Table: 1. Different Crops with their Average Yield And Economic Water Use Efficiency

Sr. No.	Crop	Production (Kg/ha)	Selling price (Rs./q)	Income (Rs./ha)	Production cost (Rs./ha)	Net profit (Rs./ha)	Net water require-ment (m^3/ha)	Profit (Rs./ m^3 water)
1	Wheat	3000	700	21000	7000	14000	5000	2.80
2	Barley	2600	600	15600	5500	10100	3500	2.88
3	Gram	1000	1500	15000	5000	10000	2500	4.00
4	Mustard	1600	1600	25600	5500	20100	3000	6.70
5	Coriander	1000	1600	16000	5000	11000	3500	3.15
6	Cotton*	1200	1800	21600	12000	9600	5000	1.92
7	Cluster bean*	1200	1000	12000	5000	7000	1800	3.89
8	Green gram*	1000	1500	15000	5000	10000	1200	8.33
9	Pigeon pea*	1200	1800	21600	6500	15100	3000	5.03

*In *Kharif* crops water requirement indicate only irrigation water requirement

Choice of Crops: High water requiring crops like rice, sugarcane, sugarbeat, etc. must be banned. Crops requiring fewer irrigations like guar, moong, arhar, gram, mustard, groundnut, toria and desi cotton should be advocated. Choice of crop should be based on higher water productivity. Cotton and wheat are main crops in command area. The water requirement of both these crops is very high and the profit/ water consumed (Rs/m^3) is low. Therefore, these crops must be substituted by pulses. If 50% area under cotton and 20% under wheat is replaced by low water requiring crops, the farm income can be increased substantially (Yadav, 2006). The area under command can be further increased and tail enders will get more water.

Table 2. Economics of Crop Diversification in Canal Command of Irrigated North-Western Rajasthan

Sr. No.	Crop	Area (ha)	Total irrigation water (ha cm)	Irrigation water saving (ha cm)	Produ-ction (q/ha)	Total Produ-ction (q)	Selling price (Rs/q)	Total income (Rs)
*Kharif**								
1.	American cotton	10	500 (5)	--	12	120	1800	216000
2.	American cotton (50%)	5	250 (5)	250	12	60	1800	108000
3.	Green gram (80%)	8	96 (2)	--	10	80	1800	144000
4.	Cluster bean (40%)	4	72 (2)	--	12	48	1000	48000
5.	Pigeon pea (10%)	1	30 (3)	--	12	12	1800	21600
6.	Castor + Moth bean (20%)	2 --	52 (4) --	-- --	12 2	24 08	1600 1500	38400 12000
Rabi								
1.	Wheat	10	500 (4)	--	30	300	700	210000
2.	Wheat (50%)	5	250 (4)	250	30	150	700	105000
3.	Mustard (35%)	3.5	105 (2)	--	16	56	1600	89600
4.	Barley (20%)	2	70 (3)	--	26	52	600	31200
5.	Chickpea (30%)	3	75 (1)	--	10	30	1500	45000

*In *Kharif* crops on an average 300 mm effective rainfall have been considered for cotton and pigeon pea and 270 mm for other *Kharif* crops. Values in parentheses indicate the number of post sowing irrigations.

Irrigation scheduling: Optimum IW/CPE ratio should be followed to optimize productivity. Critical stages be identified: If limited irrigations are to be followed then irrigate at critical stages i.e. the crop growth stages sensitive to water deficit to obtain maxim production with limited water ET deficits during critical stages. Opening and closure of canals/ farm inlet may be regulated based upon cropping pattern. Following table 3 (Anonymous, 1998-2006) explains these points clearly.

Table 3: Optimum Irrigation Schedules for different Crops in North-Western Rajasthan

Crops	**Optimum irrigation schedule***	**Optimum number of irrigations**	**Consumptive water use (mm)**
American cotton	*IW/CPE 0.7*	4	610
Desi cotton	30 DAS+SF+BF	3	540
Guar	V + P	2	287
Moong	B + P	2	250
Groundnut	V+ F+ Peg. + P	4	446
Arhar	B + F + P	3	451
Sugarcane	IW/CPE 0.9	18	1780
Wheat	IW/CPE 1.0	5	440
Mustard	V+F+P or IW/CPE 0.6	3	270
Gram	V + P	2	250
Toria	B + P	2	240
Sunflower	25 DAS + F+ Mid F + SS	4	400
Sugarbeet	IW/ CPE 1.1	9	856

Methods of Irrigation: The application method should be consistent with soil type, kind of crop, size of border strip, slope, size of stream and cut off ratio. In case of wheat 50x8m or 50x10m border size with 90 per cent cut off ratio were found better for optimum irrigation.

Table 4: Effect of Different Border Size and Cut off Ratio on Yield and Water Distribution Efficiency in Wheat (Average Of Two Years)

Border size and cut off ratio	***Mean yield (q/ha)***	***Water use (mm)***	***Distribution efficiency (%)***	***W.U.E. (kg/ha/mm)***
Border size : 4				
50 x 4 m	32.55	203	68.2	15.6
50 x 6 m	31.39	215	78.0	13.7
50 x 8 m	35.44	201	78.3	16.5
50 x 10 m	33.05	252	80.2	12.5
Cut off ratio (%) : 3				
80	33.72	203	74.8	14.8
85	33.60	213	74.5	14.7
90	34.29	235	78.4	14.4

Conservation Irrigation Method: Border strip method is suited for high flow rates and narrow row crops. Furrow irrigation is suitable for wide row crops and low flow rate. Furrow irrigation saves water without reduction in crop yields. Check basin is generally followed for tubewell irrigation but it may be practiced at tail ends with small flows in command areas as well. Under water deficit situation alternate furrow or alternate furrow in rotation saves considerable water with slight reduction in yields.

Micro-irrigation: On undulated sandy plains, high infiltration rates land leveling is cumbersome and uneconomic for conventional irrigation. Sprinkler irrigation / micro sprinklers and drip irrigation have proved highly successful under this situation. It is also gaining attention in tubewell command, canal command area in Sriganganagar. Irrigation scheduling with sprinkler has proved highly economic in case of wheat over flood irrigation.

Table 5: Effect of Different Irrigation Methods on Cane Yield, Net Income and Water Use

Irrigation methods	Yield (q/ha)		Net income (Rs./ha)	Benefit cost ratio	Water use (mm)	Water use productivity	
	Cane	Green fodder				Kg/ha/mm	Rs./ha/mm
Irrigation Methods: 4							
Flood irrigation	471.2	205.9	31076	2.40	1392.5	34.14	22.32
Each furrow	614.8	240.3	44762	2.88	1392.5	44.47	32.15
Alternate furrow	484.4	210.1	31913	2.40	929.1	52.36	34.35
Alternate furrow in rotation	609.8	238.4	44257	2.87	929.1	65.67	47.63
CD (P=0.05)	7.8	--	--	--	--	--	--

Table 6: Effect of Different Irrigation Schedules on Test Weight, Grain and Straw Yield of Wheat

Irrigation schedule	Test weight (g)	Grain yield (kg/ha)	Straw yield (kg/ha)	Water use (mm)	WUE (kg/ha mm)
Sprinkler irrigation					
IW/CPE 0.4	36.21	3731	4969	236	15.83
IW/CPE 0.6	38.92	4530	5883	286	15.86
IW/CPE 0.8	40.88	5008	6446	352	14.21
IW/CPE 1.0	41.52	5066	6512	352	14.38
Flood irrigation					
IW/CPE 1.0	41.49	5156	6715	490	10.53
S. Em $\pm$	0.57	93	157	--	--
CD at 5%	1.73	287	486	--	--

Yadav and Girdhar (1979) reported that sprinkler irrigation was more effective in reducing salinity in upper soil layers than surface irrigation. Cucumber yields was 1 to 1.5 times higher with sprinkler irrigation (Singh and Singh, 1978). It also gave 33-37% higher yields of wheat over check basin or border strip method.

Drip Irrigation: It is highly useful for sandy soil where evaporation and deep percolation are very high. Drip provides water through a network of pipes and tiny outlets at very low discharge and low pressure. The discharge rate of drip is less than infiltration rate of sandy soil, hence deep percolation are minimized. Drip is able to save 30-50% water in most of the high value vegetable crops besides giving perceptible higher production (Singh et al., 1978). In cotton, drip irrigation increased water and nutrient use efficiency at Sriganganagar.

It is highly suitable for saline water irrigation. Saline waters of EC 3-10 dS m^{-1} were successfully used in potato and tomatoes (Singh et al., 1978). It has been observed that daily drip irrigation maintained higher moisture content and pushed the salts beyond active root zone, and hence detrimental effects were minimized (Gupta and Singh, 1983; Singh et al., 1978). The high installation cost of drip lateral and emitters and clogging by salts are the major bottlenecks of drip system in its adoption on a large scale.

Keeping one lateral between two rows reduced the installation cost and water use by 50% (Singh 1978). Drip irrigation provided gainful use of nutrient management with water and provided maximum yield of tomatoes, chillies and cotton (Singh et al., 1989; Anonymous, 2005). In cotton an increase in seed cotton yield to the tune of 50 per cent was recorded by drip irrigation.

Table 7: Effect of irrigation schedules on cotton productivity

Treatments	Seed cotton yield (kg/ha)	No. of bolls/ plant	Boll weight (g)	Ginning (%)	Seed index (g)	Total water use (mm)	WUE (kg/ha mm)
I_1- 0.6 ETc Drip	1610	31.1	2.82	32.70	7.61	480	3.35
I_2- 0.8 ETc Drip	1939	35.8	3.14	33.87	7.85	582	3.33
I_3- 1.0 ETc Drip	2113	37.6	3.34	35.17	8.35	680	3.11
I_4- Flood irrigation	1701	31.5	3.14	33.99	7.52	785*	2.71
I_5- Furrow irrigation	1711	30.1	3.15	34.18	7.57	527	3.25
S. Em. ±	32	0.9	0.08	0.46	0.16	-	-
CD at 5%	91	2.6	0.23	1.32	0.44	-	-

Plastic infusion sets used in hospitals have been reused on small scale area for raising vegetables (Kolarkar et al., 1983). Keeping in view the scarcity of water in the region, drip irrigation has to be given proper attention for maximizing the production per unit of water in arid region.

Regulation of canal opening and closing: In canal commands, water availability is not regulated as per requirement of the crop coinciding with physiological critical growth stages. The farmers apply heavy irrigation due to the fear of uncertainty in availability of water during next turn. Under canal regulation system, there is no match of actual canal running with canal regulation forecasted prior to commencement of the cropping season. The farmers also face the inequitable distribution of water when canal is closed without completing its cycle due to one or other reason. The requirement of Warabandi although in terms of equity is full filled to a certain extent, but in practice the farmers at head reaches get more water as compared to tail enders. Regulation of opening and closing of canal as per cropping need will enhance productivity and economize water use.

Balanced use of fertilizers: Balanced nutrition to crops is a key component to increase yield and quality of the produce, maintenance of soil productivity and soil heath and protection of environment. In Rajasthan state, the current use of fertilizer nutrients (NPK) is 39.5 kg/ha of cropped area. The N, P and K use during Kharif of total consumption is 46, 54 and 45%, respectively. The current NPK use ratios is 88.3 : 32.6 : 1 which is much wider than the ideal NPK ratio. The use of P and K in the state is much lower especially after decontrol and removal of subsidy on P and K fertilizers in August 1992. In addition to this, there is disparity in use of nutrients among different districts. In Churu (2.4 kg/ha) and Barmer (3.0 kg/ha) districts fertilizer nutrients use is quite less in comparison to Kota (136.7 kg/ha) and Baran (102.3 kg/ha) districts.

Inadequate and imbalanced use of fertilizers produces low crop yields. It also results in further depletion of the most deficient nutrients in the soil. Under such circumstances the efficiency of water applied to the crop is decreased.

Credit availability to poor farmers: Most of the farmers in the state are economically poor. They cannot buy fertilizers and certified seeds. Due to their unawareness, the water conservation practices such as summer ploughing, mulching, conservation tillage and organic residue incorporation are not performed as and when needed. Moreover, the farmers are unaware about the technical know how of pressurized irrigation system which is the most efficient method of irrigation.

Crop diversification: In order to enhance income and productivity per drop of precious water in arid regions farmers have to go for crop diversification and integration of animal wealth with crop production in farming system.

Arid horticulture: With availability of canal water, adoption of micro irrigation-drip sprinklers in wide spaced crops, horticultural crops and vegetables, growing of low water requiring endemic cash crops like spices ker (*Capparis deciduas*) and henna (*Lowsonia intermis*) etc. income and productivity can be raised several folds. Arid fruits like ber (jujube), promegranate, bael, goonda, aonla, citrus fruits like kinno and sweet orange can be grown with minimum water supply. Buding of improved varieties of ber (Gola, Seb ad Mundia) have become quite popular in arid areas. Vegetables like chillies, tomato, spices, ladies finger, cauliflower, melons, cucumbers, bottle guard etc. will be highly remunerative. In waterlogged areas datepalm with fisheries would be an ideal propositon to enhance productivity.

Livestock based farming system: Livestock farming has been a way of life in arid areas. Nearly 20% waste land should be utilized for silvi-pasture of improved grasses of *Cenchrus ciliaris*, *C. setigerus*, *L. sindicus* with fodder trees like *Prosopis cineraria*, *Tecomella, Acacia*, *Ailainthus excelsa* etc. can be grown.

Superior breeds of cattle (Tharparkar, Rathi, Kankarej, Gir), small ruminants like Marwari sheep, Magra Goat, Jamnapari etc. should be reared to enhance income. Organic Farming: The arid region, baring canal command areas, are organic by default. Application of fertilizer nutrients in rainfed areas is hardy 3-5 kg/ha. If these nutrients are supplied through cow dung etc. Organic agriculture can be easily practices for endemic cash crops, spices, fruits and vegetables. The organic food will fetch more income in national and international market.

Value addition and marketing: To avoid glut in the market value addition and processing, at the site of production and market chain has to be developed to harness more income per drop of water use. Bountiful solar and wind energy should be utilized for processing etc. Value addition at the site of production with generate on farm and non farm employment.

Future line of work

- Soil management for maximizing effective rainfall and minimizing water losses
- Conjunctive use of canal and ground water
- Crop diversification for improved water use efficiency
- Management of shallow water tables
- Cost effective drip irrigation systems
- Fertigation technology development
- Design and evaluation of sprinkler irrigation system
- Identification of water use efficient crops, cropping sequences and genotypes
- In-situ and ex-situ moisture conservation

- Rain water harvesting and its recycling
- Minimizing non-ET losses
- Development of Agro-horti, Agro-horti-silvi and agro-forestry techniques for higher water productivity
- Integrating water management and other production technologies
- Development of Special Economic Zone for command and non command area
- Export value crops/ products
- Value addition and marketing through cooperatives etc.

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MORE CROP INCOME PER DROP OF WATER IN GUJARAT

M.C.Varshneya*

Water is not only essential for life but cannot be produced by technological means. Exploration, evaluation and exploitation of water resources are very essential for planning, developing and utilizing water. The era of crop productivity per unit of land has gone and now emphasis need to be on more crops per drop of water.

The state of Gujarat has a total geographical area of about 196 lakh hectares. The state has around 25 lakh ha under irrigation accounting to 26% of total cropped area. Eighty per cent of this is irrigated by wells, 18% by canals and 2% by other sources, mainly tank. The irrigated area varies widely from district to district.

In Gujarat, 64% of the agriculture is dependent on the vagaries of weather as against 60% at national level. The problems become more acute as rainfall is erratic with high coefficient of variation (CV). While in the high rainfall area of southeastern part of the state the runoff and erosion are the main problems, in the light soils of north-west area low rainfall makes agriculture uneconomical.

At present, the total annual water available in Gujarat is 25 BCM. More than 90% of the available surface water is concentrated in south, while the ground water potential is more evenly divided - 50% in the South, 40% in Saurashtra, 9% in the North and only 1% in the Kutch region. In total, Kutch region accounts for only 2% of the total water resources potential of Gujarat.

The major factors that have impeded agricultural productivity in the state are :

1. Variability of rainfall
2. Recurrent droughts
3. Depletion of water table
4. Deterioration of soil and water conditions due to salinity ingress

All these lead to the conclusion that appropriate rainfed water management technology is very important for this state. There are technologies that aim at better water management through water conservation, water recharge etc. These include-

1. Conjunctive use of surface and ground water
2. Watershed development and rain water harvesting
3. Ground water recharge
4. On-farm water conservation technology
5. Micro irrigation
6. Salinity prevention in coastal area

Conjunctive use of surface and ground water

Surface water development is through major, medium and minor irrigation schemes, whereas ground water development is through tube wells and shallow dug wells. The availability of water for Gujarat, as for the country as a whole, shows wide variability from region to region Table -1.

*Vice Chancellor, Anand Agricultural University, Anand - 388110

Table – 1 Regional distribution of ground water in Gujarat	
Area	**Mm^3 per year**
Saurashtra	6480
Kutch	716
N.Gujarat	4675
Central & South Gujarat	6472

From the experience of management of the major and medium irrigation schemes, it is observed that there is a wide gap between the irrigation potential and utilization. As per the detailed study by C.C.Patel (2001), water resources of Gujarat even after considering allocated shares from the inter-state rivers, are hardly 2% of the country's water resources, its share in population being 4.93% (2001). The overall irrigation potential is estimated at about 63 lakh hectares, while the utilization of irrigation potential is only 30.31 lakh hectares.

Table – 2 Details relating to irrigation potential (Lakh ha)

Items	Ultimate irrigation potential (Lakh ha)	Potential (Lakh ha) created up to		Potential (Lakh ha) utilised by	
		1997	2004	1997	2004
Surface water					
Major schemes	13.10	10.13	11.24	08.89	10.21
Sardar Sarovar	17.92	0.00	0.25	00.00	0.25
Medium schemes	4.90	3.37	3.37	03.00	3.0
Minor schemes	3.48	2.22	2.69	01.31	1.65
Total…	39.4	15.72	17.55	13.20	15.11
Ground water					
Govt. tube wells	4.0	2.87	2.87	01.77	2.86
Private tube wells	21.48	17.26	17.48	15.34	17.48
Total…	25.48	20.13	20.35	17.11	20.34
Grand Total…	64.9	35.85	37.90	30.31	35.45

Source: C.C.Patel (2001)

The data given in Table 2 shows the need of efficient use of irrigation water potential and rain water harvesting as well as watershed development programme. This will involve ensuring more efficient operation of irrigation systems, modernization of major, medium and minor projects, restoration of ground water, land shaping, land leveling, accelerating construction of field channels and drains, exploitation of ground water through tube wells, watershed project, planning, adoption of suitable crop pattern etc. In order to increase efficiency of water use, various aspects of water management have been given due importance. The State Government further made the efforts to increase the surface and ground water resources to bring more area under irrigation. As a result potential for additional 2.05 lakh ha area was created up to 2004, while 5.14 lakh ha area could further be brought under irrigation due to maximum utilization of water resources by the end of 2004.

Watershed Development and Rainwater Harvesting

Watershed development technologies refer to technologies such as construction of location specific rainwater harvesting structures such as check dams, percolation ponds, networked farm ponds and soil conservation measures such as field bunds.

Government of Gujarat, in recent years, has taken a number of measures to meet the challenges of fluctuations in agriculture. The most important programme is of conserving water. This is a three point programme, undoing construction of check dams, construction of village ponds where check dams are not feasible and construction of individual farm ponds in farmer's own fields.

In the last 50 years and more, only 4000 check dams had been constructed, while in the last four years, over 80450 structures have been created by means of government and public participation. Check dams are barriers constructed in a stream or gully to reduce the downstream velocity of the water and hold the surface run-off. The water that is harnessed can be used for irrigation and for ground water recharging. About 500 large check dams have been constructed across some of the dry rivers in the state. In Saurashtra region 100 large check dams have been erected, while work is in progress in many other areas of the state. Similarly, 1,37,000 farm ponds, 35000 *boribandh* and deepening of 3238 village ponds have been completed during the past four years.

Farm ponds can be constructed at the individual level, in low-lying areas of the farms so that the run-off water can be stored in them. The farmers put in their own labour to create a farm pond. *Boribandhs* are low-cost structures constructed for obstructing the flow of rain water and prevent soil erosion. They are especially effective when there is a high surface run-off and the rain water cannot be collected. Locally available empty cement bags or plastic fertilizer bags are used and are filled with sand to act as barriers across streams.

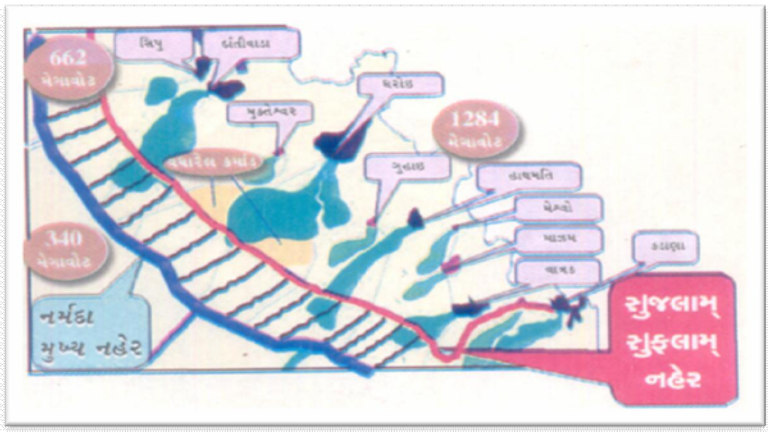
Due to the construction of check dams, even those areas that faced perennial water scarcity have seen rise in water table by 100-500 ft. Under to the programme, it was planned that at least one water harvesting structure would be erected in every village. The construction of *boribandhs*, check dams and village ponds was done by dovetailing with the existing schemes of Rural Development Department.

As the success story in Gujarat is closely linked with its unique extension effort and water conservation measures, both these activities should be vigorously pursued in order to consolidate the gains already achieved.

In addition to watershed development programme, construction of Sardar Sarovar dam up to 110 m has been completed. This dam provides adequate water for giving irrigation benefit to nearly 4.5 lakh hectares in the first phase. Moreover, available river network has been used for transferring surplus water from the dam. This water has also been used for filling village ponds, thereby recharging ground water.

Ground Water Recharge

***Brief contour of Sujalam Sufalam Yojna*:-** *Sujalam Sufalam Yojana*, having, a total length of 280 km from Kadana dam to Banas river, have been prepared, wherein 700 Mm^3 flood water, which now flows into the ocean will be diverted. By this scheme to be undertaken at the cost of Rs.460 Crore, 21 dry river and



more than 100 village ponds will be revived. Main reservoirs which are filled up to 50% capacity will be filled at 100% capacity by one million acre feet Narmada Water from Narmada Main canal out of Gujarat's share in the Narmada Project further extension work of its canals will be undertaken and check dams will be constructed barring irrigated areas. Besides, 5000 village ponds on these areas will be filled by Narmada water.

Work on distribution canal linking *Sujalam Sufalam* canal from Narmada main canal will be taken up at the cost of Rs.73 Crore, out of which approximately 4 lakh ha agricultural land will get benefit of irrigation.

On-farm Water Conservation Technologies

The SAUs of Gujarat have already recommended technologies on on-farm water conservation. In situ moisture conservation techniques such as soil mulching, organic mulching, contour bunding, compartment bunding, contour cultivation, tillage/sowing across the slope, inter/strip cropping, deep ploughing etc. were demonstrated through posters, panels and audio visual material during *Krushi Mahotsava* by agricultural scientists and departmental experts at every village. Manual of agricultural practices, have also been distributed to the villagers.

Micro Irrigation

Micro irrigation is defined as the controlled supply of water at the root zone of the crop (drip method) or aerial sprinkling at the vicinity of the plant (Sprinkler method), enabling substantial increase in water saving and irrigation efficiency. Field level studies prove that the reduction of conveyance, distribution and evaporation losses of water improve irrigation efficiency in drip and sprinkler irrigation system as compared to conventional flood irrigation system. In addition to water savings, micro-irrigation brings about substantial increase in productivity of crops and also reduce the rate of salinization and weed growth. Weed removal requires a lot of labour force and usually puts additional financial burden on the farmers.

Since Gujarat is prone to water scarcity, innovations are required to increase the efficiency of water use. Irrigation technologies that adopt more effective and rational uses of the limited supplies of water are required. The drip irrigation systems were demonstrated during the *Kisan Rath* visits to the villages. In 57 years since independence, the total area under micro-irrigation till 31.3.2005 was 34,202 ha. In just 2 years of *Krushi Mahotsavs*, the area under micro-irrigation has doubled adding a further 34,943 ha. The promotion and awareness of these systems was also generated during the month long activities in the villages. Applications for the drip irrigation systems were received at the village level and according to the existing scheme, the farmers would contribute 5% of the investment, while 45% of the funds would be made available by way of loans from NABARD. The balance 50% of the investment comprised the subsidy component, which was to be borne by the state government through Gujarat Green Revolution Company.

The demonstration of the drip irrigation systems evoked considerable interest in certain villages. The farmers were convinced about its merits and many even completed their applications, for drip irrigation systems, during the *Rath* itself.

The Gujarat Green Revolution company with investment of Rs.1500 Crore has been set up for promoting drip and sprinkler irrigation systems and provide subsidy up to Rs.50,000 per ha to farmers.

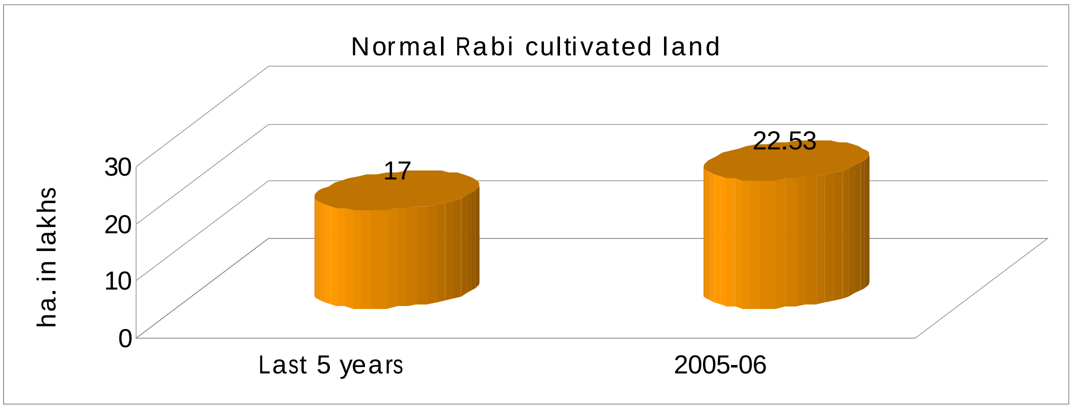
Salinity Prevention in Coastal Area

The lack of public awareness and faulty farming practices have culminated in the decline of land productivity and have increased soil salinity in the state. For decades, Gujarat waged an unsuccessful battle against salinity in its coastal areas. Gujarat, which has a 1600 km coastline, the longest in the country, has always been vulnerable to salinity. But the problem was compounded when the farmers in the coastal region started exploiting ground water in the mid 1980s. As a result salinity was increasing at the rate of 50 m annually on the Saurashtra and Kutch coasts. According to official estimates, by the late 1990s, 10.64 lakh hectares of cultivable land along the Gujarat coast had been swallowed by salinity. But, today it is turning the problem on its head with the novel scheme of building dams on rivers just before they merge into the sea, thus preventing seawater from entering the coastal lands through river channels during high tide. So far, dams have been built on 89 rivers in the coastal region. There are a total of 71 rivers in Saurashtra and 97 in Kutch. In an innovative move, the state has roped in corporations like Ambuja Cement, Tata Chemicals and NGOs like Aga Khan Trust to build more dams. The Government has also fortified the scheme by adding to it the concept of inter-linking coastal sweet water lakes, through a network of canals wherever it is technically feasible. This is especially helpful in the monsoons when surplus water can be transferred from one lake to the other. This scheme will not only check the increasing salinity but also help in water conservation besides promoting eco-tourism.

Achievements

All these measures have been responsible for dramatic changes in agriculture productivity and its sustainability. The extensive efforts, encompassing agriculture-related activities as well as water conservation have enhanced the agricultural productivity. The results of these efforts can be encapsulated as below.

Agricultural Production



The area under Kharif crop production has increased by 5-6 lakh ha. during the last five years compared to the scenario five years before. With regard to the Rabi crops, the approximate area under cultivation, was only 17 lakh ha has increased to 22.53 lakh ha in 2003-04 despite insufficient and delayed rains.

There has been an increase in production by 160% in Kharif season and by 80% in the Rabi season primarily due to the assured supply of Narmada water in the last two years and also due to the acceptance of modern agricultural practices. In terms of agricultural income, there has been an increase by 200% in the Kharif season and by 50% in the Rabi season.

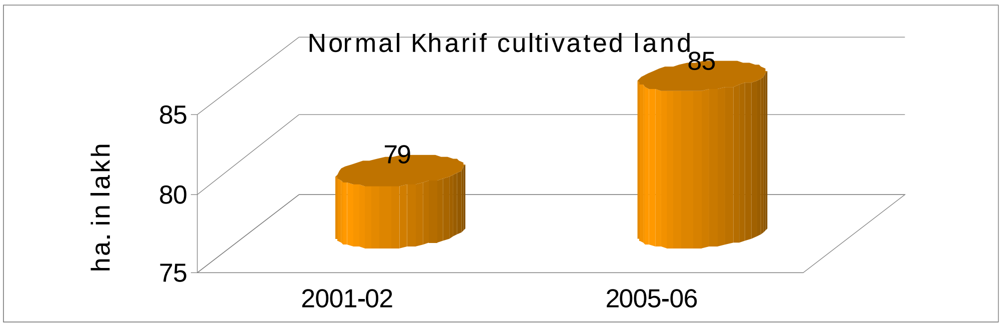
The crop production (Table-3) has been stabilized through provision of supplementary irrigation as and when required during critical stages of crop growth. This has also enabled farmers to take two or even three crops instead of one crop.

Table – 3 Production of agriculture sector : (lakh tonne)

Item	2002-03	2003-04	2004-05	2005-06	2006-07
Food grains	43.95	65.71	51.53	62.41	61.10
Oilseeds	18.78	56.55	28.99	47.34	28.46
Horticulture	-	55.60	85.10	95.86	-
Cotton (lakh bales)	18.84	40.77	55.43	65.11	87.87
Sugarcane (lakh tone jugery)	17.56	12.67	14.57	14.58	15.63
Tobacco	2.27	1.25	1.14	1.52	1.98

Income

Leaving behind the past record of fluctuating fortunes, Gujarat Agriculture appears to be entering a new era of high growth with relatively greater stability. The strategic policy interventions have helped in significantly increasing state gross domestic product from agriculture including animal husbandry (at constant 1993-94 prices). As compared to the previous year, the decline in this income was only around 12 to 15%



during 2000-2001 and 2002-03. On the other hand, the increase in income over the previous year was as high as 31% in 2001-2002 and 77% in 2003-04. The value of gross domestic product from agriculture and animal husbandry increased from Rs.11,092 crore in 2002-2003 to Rs.19,631 crore in 2003-04. It has further increased to around Rs.25000 crore in 2004-05 and is likely to surpass this figure in 2005-06.

Growth Rate

It is now widely recognized that a 10% plus overall growth rate for India is not feasible without achieving 4% growth in agriculture. The planning commission and the Government of India are making serious efforts for evolving a strategy that would ensure 9% plus growth rate during the 11th Plan. Gujarat is all set to achieve this target during the 10th plan. Simple average growth rate of gross domestic product achieved by Gujarat during the three year period 2001-2004 has been around 11%. This growth rate of Gujarat is the highest among 15 major Indian states. Recent Gujarat experience relating to agriculture provides valuable lessons for wider application to other Indian states.

Conclusion

Water conservation works were undertaken extensively through heavily subsidized individual and community oriented schemes during last four years. Check dams, *boribandhs*, farm ponds and village ponds were constructed in consultation with the communities and activities such as the cleaning of canals and deepening of ponds was also done with people's participation. Drip irrigation systems to promote the judicious use of water was emphasized by extension activities and during the Krushi Mahotsav. The programme also integrated in its ambit other activities that had an impact on agriculture. These all paved way for rapid economic development. In rural areas strategies with focus on farmers, have wider ramifications for rapid economic growth of Gujarat as a whole.

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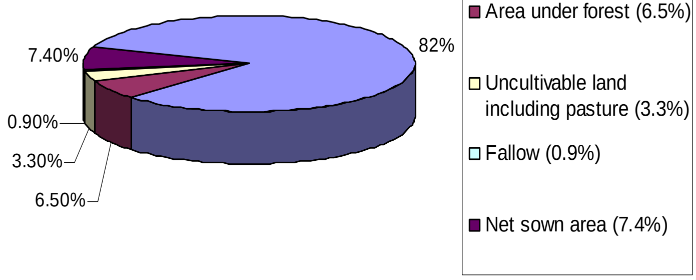
WATER USE AND ENHANCEMENT OF PRODUCTIVITY TOWARDS OPTIMISED BENEFITS FROM EVERY DROP OF WATER IN KASHMIR

Anwar Alam*

Introduction

The State of Jammu and Kashmir (J&K) has a net geographical area of 10.139 million hectares (Mha) excluding 12.0849 Mha under the occupation of Pakistan and China. It has four geographical zones viz., sub-tropical and intermediate zone falling in the Jammu Division and temperate Valley and cold arid zones of Ladakh in the Kashmir Division. The physiography of the state generates a variety of macro and micro climatic regions with a rich bio-diversity suiting to a wide range of plants / crops and animal species. The annual precipitation varies from region to region - 92.6 mm in Ladakh, 650-1000mm in Kashmir valley and 1115 mm in Jammu region. Like rest of the country Jammu and Kashmir State is predominantly an agricultural state growing food grains, horticultural produce, animal husbandry, forestry, fishery, sericulture and allied products engaging 80% of the population accounting for 36.3% of the net domestic produce of the state. Only 18% of the net geographical area is arable including forest, out of which net cultivated area is 7.36%. Over 5 decades, net sown area has increased from 0.614 Mha to 0.736 Mha. The cropping pattern is dominated by climate and change in eating habits.

Fig.1 Land use pattern in J&K
Net geographical area 10.139 Mha



Mean annual precipitation in Kashmir Valley (Lower belts) is about 809.6 mm and more than double the precipitation mostly in the form of snow on high altitudes (Himalayas). Average evaporation of the lower belts of Kashmir Valley is 936.6 mm which is 127.6 mm more than average precipitation necessitating irrigation for assured crop. Fig. 1 gives the land use pattern in J&K. Precipitation in the Valley in the form of rain and snow varies with season. The seasonal variability in perception in the Kashmir valley is given in table-1.

Table 1: Seasonal Variability in Precipitation in Kashmir Valley

	Precipitation
Spring season	27%
Summer	23%
Autumn	7%
Winter	43%

*Vice-Chancellor, Sher-e-Kashmir, University of Agricultural Sciences & Technology of Kashmir, Srinagar (J&K)

Sources of Irrigation Water

The sources of irrigation water in Kashmir division are canals, tanks, wells etc. Streams and canals account for 94.4%. The area irrigated by farmer managed irrigation canals (*zamindari kuhls*), which was more than 85% during 1950 whose command has reduced to 53% of the total irrigated area.

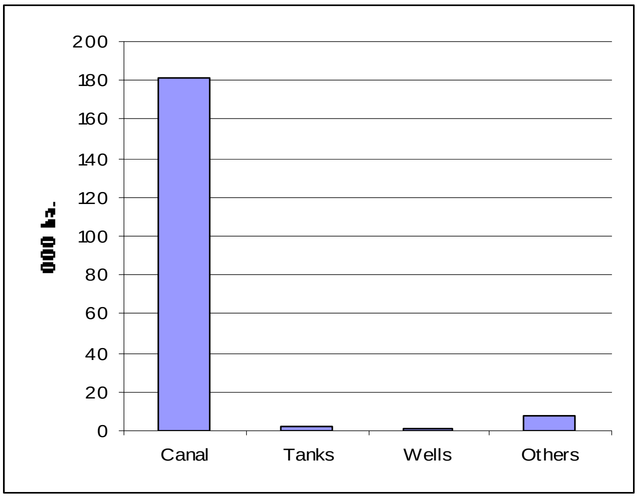


Fig. 2 Sources of irrigation of Kashmir Valley ('000 ha)

Out of 192.12 kha irrigated in Kashmir Valley, which is 56.7% of net sown area, rice alone is 136 kha (70.8% of irrigated area). State has considerable ground water potential both in Jammu and Kashmir division but not exploited except some in Jammu Division due to following reasons:

- Lack of electrical power required for lifting water.
- Lack of proper ground water survey
- Lack of coordination between governmental agencies dealing with water
- Lack of technical staff in banks that could held and fund ground water projects.
- Lack of block-wise ground water evaluation data.
- Fragment land holding and their size
- Dominance of traditional crops and cropping pattern.

Water Requirement of Crops:

Water requirement of different crops, given in Table 2 and 3 range between 300-2500 mm.

A study on irrigation water requirements of paddy was conducted on Marwal Canal command area of Kashmir. Irrigation water requirement at the outlet of the main canal was calculated considering evapotranspiration, conveyance losses, application losses and effective rainfall (Raina A., 1987) aggregating to 1284.6 mm (Table 4).

Table 2: Water Requirements of Different Crops (mm)

S. No	Crop	Water requirements(mm)
1.	Rice	900-2500
2.	Wheat	450-650
3.	Maize	500-800
4.	Soyabean	450-700
5.	Tomato	600-800
6.	Pea	350-500
7.	Potato	300-600
8.	Onion	500-600
9.	Cauliflower	300-450

Source : K. N. Shukla et. al., 2005

Table 3: Water Requirement of Some Important Fruit Crops in Hilly Regions

S. No.	Crops	Water requirement(mm)
1.	Apples	900
2.	Almond	880
3.	Cherries	600
4.	Peaches	600
5.	Pears	600
6.	Strawberries	300
7.	Grapes	530

Source: K.N. Singh, 2004

Table 4 : Water Requirement at Different Stages of Growth of Paddy

S. No.	Activity	Period	Gross Irrigation water requirement (mm)
1.	Water requirement during seeding cum puddling	Second week of April First week of May	150.0 100.0
2.	Water requirement during transplanting and puddling	3-5 days	100.0
3.	Transplanting /establishment in the field (15th May to 4th June)	15th May to 21st May 22nd May to 28th May 29th May to 4th June	49.83 51.08 50.45
4.	Tillering/pinnacle development (5th June to 2nd July)	5th June to 11th June 12th June to 18th June 19th June to 25th June 26th June to 2nd July	51.70 51.95 52.01 54.58
5.	Flowering	3rd July to 16th July	211.21
6.	Dough formation	17th July 27th August	209.5
7.	Seed Maturity	28th August to 17th September	152.27
Total			**1284.58**

Methods of Irrigation

The methods used for water application that have direct bearing on water use can be flooding, furrow method, sprinklers irrigation and drip irrigation.

Flooding: Flooding irrigation is the most widely employed irrigation method in Kashmir specially for rice. Under this method, irrigation water is conveyed through a channel, un-lined or lined, flooding the basins created beforehand. There are two methods of flooding (a) direct and (b) cascading, both are in vogue. In wheat, maize, pulses and oilseed crops, border irrigation, a form of flooding irrigation, is practiced where uniformly graded strips are created using small bunds which are dismantled after the crop. Water is applied in basins or borders through siphons, spills or bund breaks. Under open ditch conveyance and flooding method of irrigation, only about one half of the water released reaches the plants. The plants actually use 50% of the water delivered. Thus, the efficiencies range between 24-40%. Loss of water use efficiencies could be due to conveyance losses resulting from seepage and evaporation, poor land preparation, lack of know-how and excess water application.

Furrow Method: Water is applied through a series of parallel furrows which are in turn connected with the main channel. It is suited to crops like potato, sugarcane, vegetables on raised bed. It can easily save 20-30% of water over flooding method.

Pressurized Irrigation System: These systems deliver water under pressure or gravity head and can be grouped into (a) sprinklers (b) micro-irrigation and (c) piped distribution for surface irrigation. Table 5 presents different types of pressurized irrigation systems available.

Sprinklers are best suited to sandy soils with high infiltration rates although adaptable to most soils. The average application rates of sprinklers are chosen to be less than basic infiltration rate of the soil to avoid wastage. Well managed sprinklers can save water up to 60% and yield advantages up to 50%. Table 6 gives different types of sprinklers available.

Drip irrigation system is most efficient irrigation in terms of irrigation water conservation and application. It delivers water very near to root zone avoiding runoff, evaporation, over application etc. Table 7 gives water saving and yield increase under drip irrigation system.

Subsurface drip irrigation system though a bit difficult to lay, further increases water savings. Advantages increase by integrating fertilizer application with drip irrigation, commonly called fertigation, which improves not only water use efficiency but also fertilizer use efficiency. Pressurized irrigation systems are capital intensive. To make them affordable to small and marginal farmers and kitchen gardeners low cost options have been developed and introduced,

1. Bucket kits to drip irrigate 20 – 25 m^2 plots
2. Drum kits to irrigate about 125 m^2 plots
3. Shiftable Drip System with shiftable lateral lines irrigating 10 rows instead of 1 row
4. Gravity Fed Micro-irrigation system for hill agriculture
5. Low Energy Pressure Application (LEPA)

Table 5 : Different Types of Pressurized Irrigation Systems

	Pressurized Irrigation systems		
Sprinkler	Set systems	Periodic move	• Hand move laterals (including drag hose & hop along). • Low technology gravity sprinklers. • Perforated pipe (spray line.) • End tow lateral. • Side rolls lateral. • Gun sprinklers (static). • Boom Sprinklers.
		Fixed (Solid set)	• Hand move laterals (installed and removed once per person.) • Permanent buried laterals.
	Continuous move systems	Traveling (rain gun)	• Hose reel. • Cable winched.
Micro irrigation	Drip Emitters	• Centre pivots. • Linear move. • Long flow path. • Orifice emitters. • Vortex Emitters.	
	Line source Tubing	• Single chamber. • Double Chamber. • Porous Wall.	
	Bubblers	• Pressurized Bubblers. • Low head bubblers.	
Piped distribution for surface irrigation	Low pressure pipelines		

Table 6: Classification of Different Agricultural Sprinklers

Sprinkler Type	Operating Pressure (kg/cm^2)	Flow rate (l/hr.)	Wetted diameter (m)
Micro/low flow sprinklers	Low (1.5 – 2.5)	300-1500	12-20
Conventional sprinklers	Medium (2.5-3.5)	1500-3000	24-35
Gun Sprinklers	High (4.0 – 6.0)	5000-45000	60-80

Table 7: Water Saving and Yield Increase Under Drip Irrigation System.

Sl. No.	Crops	Water saving (%)	Yield Increase (%)
1.	Grapes	65-70	30
2.	Pomegranate	50-55	30-89
3.	Custard apple	50-55	20
4.	Papaya	68	77
5.	Sugarcane	60	5-10
6.	Cotton	53	26
7.	Tomato	30-40	5-30
8.	Brinjal	56-62	60
9.	Okra	55	8
10.	Cauliflower	35	40
11.	Cabbage	60	24
12.	Ridge Gourd	60	17
13.	Potato	5-15	46
14.	Chilly	62	44
15.	Radish	77	13
16.	Bottle Gourd	12	47
17.	Onion	17	21
18.	Lady finger	65	33.3

K. N. Shukla et. al. 2005

Moisture Sensitive Growth Periods of crops (Critical Growth Stages): During certain stages of growth plants are sensitive to water deficit leading to reduction in yield, which is irreversible. Moisture sensitive periods of some of the crops is given in Table 8.

Table 8 : Moisture Sensitive Periods of Some Crops

S. No.	Crop	Moisture sensitive periods
1.	Rice	Pinnacle initiation, heading and flowering
2.	Maize	Tasselling, silking and early grain formation
3.	Wheat	Crown root initiation, tillering and heading
4.	Sunflower	Flower bud initiation, head initiation, flowering and milk stage.
5.	Potato	Tuber initiation to tuber maturity
6.	Chilies	Flowering

* Source : K. N. Singh , 2004

Deficit Irrigation Practices: There is a growing interest in deficit irrigation, restricting water application such that resultant mild moisture stresses occur with minimal effect on yield. It is suited to situations where water is scarce. Water stress during regulative growth has favourable effect on the root growth contributing to more effective use from deeper layers. Micro irrigation systems enable practice of deficit irrigation.

Laser Land Leveling: Precision land leveling enhances water use efficiency and consequently water productivity. It is also helpful in practicing aerobic farming using raised bed planters. Jat et al. studied water saving by precision land leveling and raised bed planted wheat and rice compared to conventional practice and found distinctive results as depicted by Fig 3, 4 and 5. They reported total water use by wheat crop as 5270 m^3/ha and 3525 m^3/ha on traditionally leveled field and laser leveled field respectively effecting a water saving of 26 through laser land leveling.

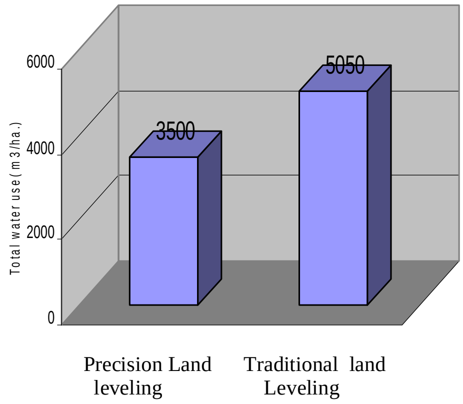


Fig 3: Total water use(m^3/ha) in wheat under precision and traditional land leveling

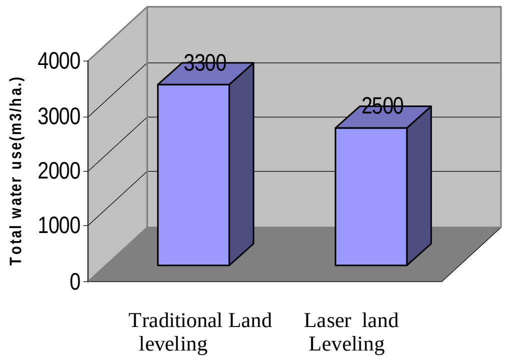


Fig 4: Effect of laser land leveling on total water use in wheat planted on raised beds

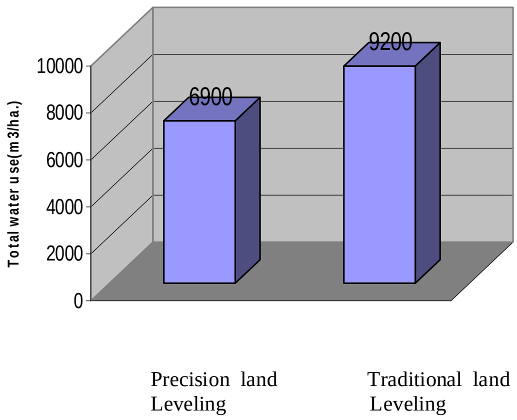


Fig 5: Effect of Land Leveling on Rice in Sandy Loam Soil

In a similar study on rice 9200 m^3/ha and 6900 m^3/ha water was used by traditionally leveled and laser leveled fields respectively. Laser land leveling improves application and distribution efficiencies of irrigation, ultimately leading to higher productivity (Table 9).

Table 9: Effect of land leveling on yield and water use efficiency

Levelling index(cm)	Water use efficiency (kg/ha-cm)		Yield (q/ha)	
	Wheat	Bajra	Wheat	Bajra
1.2	166	120	46.6	37.3
2.0	138	106	42.2	34.2
2.5	128	99	39.3	32.9
3.0	116	92	36.5	31.4

Water Harvesting Structures

If rainwater seepages and snowmelt wastages are minimized, more area could be irrigated and productivity enhanced by overcoming moisture stresses, especially during critical growth stages.

Water productivity improves if cold water coming from kuhls are impounded for some time to warm it up before application. The major sources of water supply are springs and small rivulets with limited discharges ranging between 2-20 lpm. In higher reaches discharge is still less (0.5 – 5 lpm). Some of the water harvesting structures and practices employed are as follows:

1) Hill Spring Outflow Harvesting: Storing spring water in plastic lined tanks can enable the farmers irrigate their crops at critical stages.

2) Diversion and Harvesting of Spring Water: Water from perennial springs can be diverted through field channels and underground pipes which in turn could be stored in plastic lined or pucca tanks.

3) Inter-terrace Runoff Harvesting: at suitable sites, small dug outs with plastic lining and pucca tank can be constructed and stored water used for protected irrigation and bringing additional area under irrigation.

4) Harvesting Sub-surface Streams: Sub-surface water streams keep on flowing in the valley in the upper portion of the watershed round the year, which can be harvested in ponds/tanks and stored water used for irrigation. Flow from such sources is about 0.01 – 0.1 cumec.

5) Contour Bunds: Earthen bunds on contour, 5-10 m apart, with inward slope can conserve rain water.

6) ‘Zing’ Water Harvesting Structures: Water harvesting in cold desert of Ladakh can be done by constructing ‘Zing’ (small pond or reservoir, diversion channel, and artificial glaciers).

7) Earthen Check Dams: The earthen check dams of small dimensions can be utilized for storing and recharge of ground water.

8) Non-Perennial Streams: Such streams can be diverted and water stored in sealed water harvesting structures and water can be utilized during water stress periods.

9) Roof Water Harvesting: Rain water harvested from roof can be utilized for domestic as well as irrigation purposes.

10) LDPE Dykes: Low cost LDPE dykes can be constructed at a number of places to retain run off flow for use in irrigation.

11) Moisture Conservation Techniques: Gully plugging structures, contour trenches, organic mulching, bunding etc., help in insitu water conservation, and ground water recharge.

Foodgrains

Foodgrains – cereals, pulses and oil-seeds are essential components of food security of India and J&K state is no exception. Dietry habits of the people have changed with time. In Jammu, chapatti is widely eaten, in the Valley staple food now is rice, whereas Ladakh, people who consumed barley are also becoming rice eaters through PDS (Public Distribution System). As of now, J&K is a food deficit state. Table 10 gives area, production and productivity of food grains in J&K.

Table 10: Foodgrains Area, Production and Productivity in J&K (2003-04)

Total area under cultivation (lakh ha)				
	State	Jammu	Kashmir	Ladakh
Rice	2.60	1.27	1.33	-
Maize	3.21	2.16	1.05	-
Wheat	2.55	2.50	0.01	0.04
Pulses	0.28	0.182	0.09	0.008
Oilseed	0.63	0.18	0.45	0.0007
Total(major food crops)	8.64	6.11	2.48	
Production of food grains (Lakh Tones)				
Rice	5.05	2.00	3.05	-
Maize	5.32	4.14	1.18	-
Wheat	4.54	4.54	0.001	0.004
Pulses	1.30	0.84	0.48	0.050
Oilseed	0.42	-	-	-
Average productivity (q ha^{-1})				
Rice	19.43	17.48	20.96	-
Maize	16.59	19.13	11.31	-
Wheat	18.03	18.21	9.90	-
Pulses	5.01	4.79	5.24	6.25
Oilseed	6.68	-	-	-

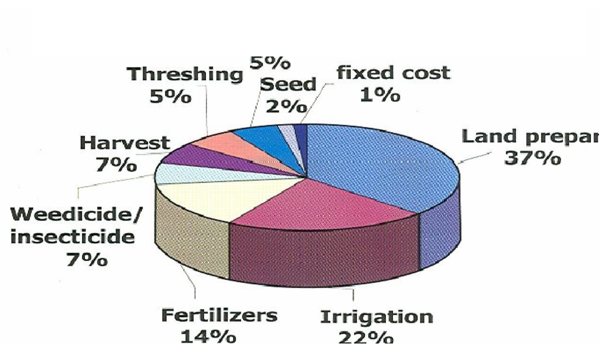
According to an estimate against a requirement of about 2 MT. of food grains annual production is only about 1.62 MT. In addition, food grains are needed for feed for the livestock to get over acute shortage of meat. Under irrigated farming conditions, many farmers are harvesting about 10.0 t/ha of paddy using university varieties and package of practice. Farmers practice mostly flood irrigation. Productivity levels are extremely low under rainfed conditions barring exceptions like maize in Doda district.

Rice-Wheat: Rice raised under cyclic water disappearances and irrigation saves about 35 water without adversely affecting productivity. Paddy and wheat raised on raised bed using Raised-Bed Planter with irrigation in furrows saves about 35-50 water. Direct seeded rice is steadily gaining ground in rice-wheat belt of Indo-Gangetic plains. According to one study against 5000 L of water per kg of rice, raised using Raised Bed Planter and Zero-tillage, system using Zero-Till Drill required only 3000-3500 l of water per kg of rice respectively, a water saving of over 30 with yield advantage of 10-15. Trials conducted in the Valley gave a water saving and substantial reduction in cost of cultivation. This new practice needs to be popularized.

Puddled fields show soil cracking behaviour very early whereas direct seeded rice soils generally do not crack under water stress conditions. Irrigation scheduling can be guided by visual symptoms such as hairline cracks combined with plant water-stress symptoms. Direct seeded rice does not require continuous submergence and can be safely irrigated at hairline crack stage to obtain yield without penalty, thus conserving irrigation water. Direct seeded rice is generally established by many farmers using the stale-bed technique avoiding pre-plant irrigation, thereby saving water and suppressing weeds. Some farmers prefer sesbania co-culture (brown manuering) using a drill, which can sow paddy and sesbania simultaneously and sesbania knocked down after 25-30 days using 2, 4-D creating mulch, which reduces weeds and conserves water besides adding organic manure. In rice-wheat rotation leaving, which straw serves as surface mulch suppressing weeds and conserving moisture.

Rice cultivation uses roughly five times more irrigation water than used for wheat cultivation. Well managed rice uses about 150 cm of water whereas wheat uses only 30 cm of irrigation water. Profitability of wheat production was highest with raised bed planting followed by zero-tillage and lowest with conventional tillage (Chandra et.al., 2007).

A field survey (72 farmers) in Haryana and Punjab, where conventional puddled transplanted rice was compared with recently introduced direct seeded rice revealed as in Fig.6. It is found that in 67 cases, farmers obtained either equal or higher yield by direct seeding over conventional transplanted rice. The marginal yield penalties in 33 cases were mainly due to inexperience and un-timeliness, inappropriate soil moisture etc. Direct seeded paddy gave economic savings of US$ 70-120 per ha through reduced cost in land preparation (77), irrigation water use (15) and labour (8).



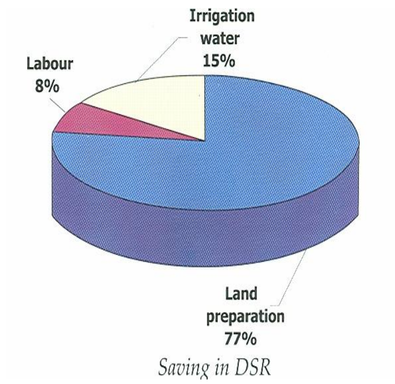


Fig.6. Comparative input cost in puddle transplanted rice and DSR (1)

Table 11 Comparative Economics of Direct Seeded Rice and Puddled Transplanted Rice

	Transplanted	Direct seeded
Total cost (US $) Net income (US $)	518 ± 48 445 ± 63	275 ± 47 354 ± 48

Source: Rice-Wheat Conservation Tech Bulletin

Continuous submergence of rice crop throughout the growth period can lead to toxic conditions. Unless mechanically agitated oxygen shortage starts after 14 days of continuous submergence, followed by high concentration of sulphides and methane, which can damage root hairs resulting in stunted growth and yellowing. Therefore, periodic drainage is advisable. Lot of irrigation water can be saved by irrigating paddy fields 2 days after disappearance (Table 12).

Table: 12. Irrigation Schedule Under Limited Water Supply

Growth stage	Water level	Remarks
Transplanting. To 7 DAT	± 5cm	Submergence essential for root establishments
8 to 35 DAT	± 5cm after 2 days of disappearance of water	Stress is detrimental
36 to 40 DAT	± 5cm	Submergence (stress at panicle initiation stage is detrimental
41 to 60 DAT	± 5cm after 2 days of disappearance	
61 to 70 DAT	± 5cm	Flowering stage is essential
71 to 90 DAT	Alternate wetting and drying	

Maize : Maize occupies 330.2 kha in J&K of which only 9.7 Kha. is irrigated. In Kashmir Valley, 114.8 kha is under maize, of which 26.2 Kha is irrigated. Though maize is very efficient in water use, irrigation at critical growth stages is essential particularly during knee-high, tassel ling and silking stages. For higher yields pre-sowing irrigation and irrigations at critical stages are essential. Khan et al. 1996 found furrow irrigation superior for maize with water expense efficiency of 126.12 kg ha^{-1} cm^{-1}.

Moong and Cowpea: Water requirement of moong is 300-400 mm. critical stage for irrigation is flowering and pod development. Water logging at critical stages is detrimental. Cowpea is a drought tolerant crop. Its water use efficiency is 100 kg ha^{-1} cm^{-1}. Moisture stress at pod filling results in drastic reduction in yield. Excessive irrigation reduces harvest index.

Fruits and Vegetables: Kashmir grows wide range of temperate fruits and vegetables. Table 3 & 7 give water requirement of selected fruits and vegetables. Fruits are raised in large grids are well suited for drip irrigation. Table 7 indicates water saving and increase in yield due to drip irrigation. Water saving ranges between 35-70%. Table 13 gives the irrigation water requirement of major vegetables. Micro-irrigation where convenient can save 25-50% of water easily along with yield advantages. Table 14 gives water use, critical stages / periods in various fruit crops by micro-irrigation and conventional methods.

Table: 13. Irrigation Water Requirement and Critical Stages of Irrigation for Some Vegetable Crops Having Varied Rooting Depths.

S. No.	Name of the crop	Rooting pattern	Water requirement (cm)	Critical stages of irrigation
1.	Onion	Very shallow to shallow rooted	15	Bulb formation and enlargement
2.	Lettuce	-do-	18	Head formation
3.	Cabbage	-do-	12	Head formation and enlargement
4.	Cauliflower	-do-	12	Throughout the whole vegetation period
5.	Celery	-do-	30	Throughout the whole vegetation period
6.	Potato	-do-	30	Stolon formation, tuberization and tuber enlargement
7.	Spinach	-do-	9	During the whole vegetation period
8.	Pole bean	Moderately deep to deep rooted	15	Flowering and pod development
9.	Beet	-do-	18	During the whole vegetation period
10.	Carrot	-do-	18	During the whole vegetation period
11.	Cucumber	-do-	15	Flower bud development and early fruit development
12.	Brinjal	-do-	18	Flower development, fruitset and after each harvest
13.	Muskmelon	-do-	24	Flower bud development and early fruit development
14.	Pea	-do-	18	Beginning of flower bud development and pod filling
15.	Chilli	-do-	18	Tenth leaf to flower, fruitset to fruiting and after periodical harvests
16.	Summer squash	-do-	18	Flower bud development and early fruit development
17.	Artichoke	Very deep rooted	12	Flower bud development
18.	Lima bean	-do-	12	Flowering and pod development
19.	Sweet potato	-do-	18	40-50 days after planting at tuber formation
20.	Tomato	-do-	24	Flower development, fruitset and after each harvest

**Acre-inch x 102.8 = cubic metre*
Source: Shanmugavelu, K.G. (1993). Production Technology of Vegetable crops

Table-14: Water Use, Critical Stages/ Period and Yield for Various Fruit Crops in Micro-Irrigation and Conventional Methods

Crops	Critical stages/ periods	Yield (q ha^{-1})		Increase in yield (%)	Water supplied (cm)		Water saving (%)	Water use efficiency (Kg ha^{-1} cm^{-1})	
		Conv.	Drip		Conv	Drip		Conv.	Drip
Apple (5 year old)	Fruit set to fruit development stage (April – August)	9.6	19	97.91	100	60	40	9.0	31.0
Stone fruit Cherry and Apricot (20-25 years old)	Fruit set to pit hardening stage (April –May)	125	182	45.6	80	55	31.25	156.0	330.0
Banana	Fruit set to full grown stage Mar-May (W. India) Dec-June (Bihar) Mar-June (Plains)	575.0	875.0	52	176	97	45	326.0	902.0
Grape	Fruit set , fruit development and maturity April-June (N. India) Oct-Mar and Apr-May (W. India)	264	325	23	53	27	48	498	1203
Citrus (General)	Fruit set and development stage (Mar-June)	100	150	50	166	64	61	60	234
Kinnow	Fruit set to fruit growth stage	68	98	44	22.1	17.3	21.71	370	566
Lemon	-do-	15	27	80	23	17.5	23.91	65	154
Pomegranate	Fruit set to physiological maturity Jan-Apr (Ambe bahar) Oct-Dec (Mrig bahar)	55	109	98	144	78.50	45	38	138
Papaya	Summer seasons for young plant Fruit set to maturity stage	134	243	75	228	73.30	68	58	331
Guava	April-June (ambe bahar) Oct-Feb (Mrig bahar)	0.16/ plant	0.22/ plant	37	6.4 m^3/ plant	5.21m^3/ plant	27.3	3	4

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MORE CROP AND INCOME PER DROP OF WATER – A STATUS REPORT IN RESPECT OF WEST BENGAL

Surajit Mallick* & P.K. Bandyopadhyay*

Introduction

West Bengal, an eastern state of India covering total geographical area of 8.81 Mha and net sown area of 5.93 Mha, is located within the Ganga-Meghna-Brahmaputra basin. The state is a land of plentiful rainfall (1200 to 2500 mm annual rainfall), rich alluvial aquifers holding some 31 billion cubic meters (BCM) of ground water (WIDD 2004), which is accessible at 5 to 10 meters below ground level in 95% of villages (3^{rd} MI Census, GOI 2001). In terms of per unit availability of ground water, West Bengal ranks second (MCM of ground water/1000 hectare of net cultivated area) and third (MCM of ground water/100km^2 of geographical area) among major Indian states. Six distinct agro-climatic zones, namely Hilly, Tarai, Old alluvial, New alluvial, Red laterite and Coastal region are prevailing within the state.

It is generally agreed upon that the adoption of ***'green revolution technology'*** based on High Yielding Varieties (HYV), fertilizer, pesticides and irrigation are the root causes for agricultural growth of the state besides land reforms and other policies of the state. In this context the role played by irrigation is considered as the basic productivity input for the agricultural production. It is seen that during the green revolution net sown area in the state was decreased while there was an increase in crop productivity. Due to continuous development of irrigation, till now 45% of the total cultivated area is brought under irrigation and as a result, the average cropping intensity for the state has increased to 184%. The massive development of irrigation potential, however, changed the cropping pattern to a considerable extent.

Major Crops Grown under Irrigated Condition

With the changes in fertilizer consumption from 110 kg/ha to 130 kg/ha for last 14 years (year 1992-93 to 2005-06), the following table (Table 1) shows the changes in the area and productivity of some major crops in this state, grown under irrigated conditions.

Table 1 The changes in area and productivity of some major crops, grown under irrigated conditions in West Bengal from 1992-93 to 2005-06

Crops	**Area (lakh ha)**		**Change (%)**	**Productivity (t/ha)**		**Change (%)**
	1992-93	**2005-06**		**1992-93**	**2005-06**	
Rice (boro)	9.34	13.81	+ 47.8	2.70	2.92	+ 8.2
Wheat	2.72	3.66	+ 34.6	2.20	2.11	– 4.1
Pulses	2.64	2.23	– 15.5	0.68	0.78	+ 14.7
Oilseeds	4.30	6.43	+ 49.5	0.80	0.97	+ 21.2
Potato	2.21	3.54	+ 60.2	21.6	210.53	+ 874.7
Jute	4.93	5.58	+ 13.2	1.95	2.55	+ 30.8

Water Resources of West Bengal

The state of West Bengal is apparently rich in water wealth due to good amount of precipitation, presence of many perennial rivers, large volume of runoff and vast areas of alluvial soil and minimum hindrance of soil salinisation. Twenty two river basins and 4 large drains covering 7.62 Mha of catchment area enrich the annual

*Bidhan Chandra Krishi Viswavidyalaya, Mohanpur – 741252, Nadia, West Bengal

water resources to the tune of 14.75 Mha m in which 13.29 Mha m, is from surface and 1.46 Mha m is through ground water resources. However, due to technical and geological constraints and present level of infrastructure, it would be possible to harness only 40% of the available water resulting only in 5.31 Mha m of surface water which can be utilized. It is estimated that the state would have a short fall of 4.23 Mha m in near future unless curative measures are not initiated to decrease the wastage and increase the utilization efficiency. A major portion of this deficit can be minimized by efficient water management in agricultural sector as 80% of the total water resources are being utilized for irrigation in crop fields which is gradually decreasing due to more demand of water from power and industry sectors.

Irrigation Status

Irrigation scenario of the state reveals that the total irrigation potential of 5.37 Mha has been created till 2005-06 out of which 1.56 Mha is under major irrigation systems, and 3.81 Mha under surface minor and ground water resources. The growth of irrigation potential created and utilized under different irrigation systems for the last ten years projects a wide gap between irrigation potential created and utilized which is more in major irrigation system (74%) compared to ground water resource (82%). The ultimate irrigation potential reflects that there is a wide scope to increase the irrigation potential in future particularly under major irrigation system compared to minor irrigation.

Three irrigation projects namely DVC, Kansabati and Mayurakshi are in operation and supply irrigation to 1.5 Mha. One more major irrigation project in North Bengal is under construction. Besides major irrigation projects, irrigation water is also available from many rivers through lift irrigation and different water bodies. Ground water source are also used extensively to irrigate 42% of the total irrigated land. Till 2005-06, 8156 deep tube wells (3844, high; 609, medium and 3703, low), 3686 shallow tube wells and 7388 open dug wells besides a large number of private tube wells are in operation.

Irrigation Scenario in the Major Irrigation Projects

Canal Command

In major irrigation commands of the state, regulatory structures are available at distributory and at minor levels. Command Area Development Agency (CADA) has started functioning in all the major irrigation commands and completed field channels only for 15% of the command area. In kharif season, canals are usually open but close during rainy days and irrigation authority regulates the inflow of canal water at the distributory level. Non-existence of regulatory structures at outlets results in continuous flow of water at the field level. Farmers do not prepare field channels during kharif and irrigate the paddy fields by wild flooding but prepare it during rabi and summer seasons.

During kharif season, canal water is available for 60 days starting from the middle of July up to middle of October. However, in rabi season, canal water is available on rotation usually from December to end of January. In summer season also, the water is available on rotation for 60 days starting from 1st week February up to middle of April. Farmers are usually informed about the time of release. However, due to short availability of irrigation water particularly during summer season, farmers have a tendency to over irrigate the crops.

The main problems of the systems are siltation, weed infestation, deterioration of control and measuring structures, tampering or removal of outlets, cuts and breaches in minors and distributaries etc. Local disputes in water management and mounting arrears of irrigation charges are some other important problems. If the problems are analyzed, it is seen that poor performance of the canal irrigation systems at present are due to lack of outlay, cost escalation, deterioration of the old irrigation system, lack of coordination between different departments related to irrigated agriculture, problems of water logging, salinity, lack of conjunctive use of surface and ground water and lack of farmers involvement in management of irrigation water.

Tube well Command

In deep tube well commands, the farmers usually follow crop sequences depending on socio-economic status of farmers and market demand. Tube wells are usually idle in kharif season excepting some supplemental irrigation for winter paddy but are in use during non-monsoon season. Irrigation utilization pattern of tube wells, however, depends on the cropping system followed in rabi-summer months. It is observed that total days of tube well operation in whole year decrease with increase in area under summer paddy although the total running hour gradually increases. In summer paddy dominated areas, deep tube wells run usually for 15 hours a day continuously for one month during peak summer season which obviously reduce the average life of the pump. Taking gross water requirement of summer paddy as 125 cm, it is calculated that a deep tube well can supply optimum irrigation only up to 65% of the total irrigation command. Under such situation, farmers usually keep the remaining portion of land in a command fallow on rotation, thereby decreasing the efficiency of the system. For getting higher productivity, farmers usually adopt medium and long duration rice varieties where irrigation is required till the last week of April when water table recedes to alarming depths. Under such situations, farmers usually lower their pumps to a depth of 2-3 meters below the ground.

Unlike major irrigation commands, farmers generally follow recommended irrigation scheduling for most of the crops excepting summer rice. In summer rice, the farmers have a tendency to keep the crop under continuous submergence that depends on the land situation, resulting deeper submergence in low lands and in turn, over irrigation occurs. In almost all the tube well commands, irrigation water reaches the field through earthen channels, thereby decreasing the potential discharge at field level. In recent years, due to over withdrawal of ground water, quality of irrigation water has deteriorated to a large extent. It is reported that excess arsenic (> 0.05 mg/l) is found in 79 blocks of eight districts of the state. Excess fluoride (> 1.5 mg/l) is also found in laterite belt of the state.

The level of ground water development in the state varies from as high as 84.6% in Nadia district to as low as 5% in Jalpaiguri district, the average for the state being 41.3%. The Central Ground water Board (CGWB) currently uses a methodology called the GEC 1997 to classify blocks into safe, semi critical, critical and over-exploited. Earlier as per the old methodology (GEC 1984), blocks were categorized into white, grey, dark and overexploited. Thus, none of the 17 districts fall in the 'overexploited' category. As per ground water estimation carried out jointly by the State Water Investigation Directorate (SWID) and the Central Ground water Board as per the GEC 97 methodology, of the 269 blocks in the state, as many as 231 blocks (or 86%) were declared 'safe', while 37 (or 14%) blocks were declared 'semicritical' and only 1 block was put in the 'critical' ground water category (Ray Chowdhury, 2006). Table 2 explains the net ground water available for irrigation with tube well density (number of tubewells/1000 hectares of cultivable land) (Mukherji, 2006). The results show that tube well density is very low even in very high ground water potential blocks, showing that if anything, there is an under-exploitation of ground water resources in the state and that there is further scope of ground water utilization without putting ground water sustainability at risk.

Problems and Suggestions in Major Irrigation Commands

There are some problems in functioning of the major commands (Table 3a, b). For increasing the water conveyance efficiency of the system, the suggestive measures may be considered for optimization of irrigation waters both for canal and tube well commands in this state.

Table 2. Net Ground Water Available for Irrigation (MCM/1000 ha of cultivable land) versus Density of Tube wells (No. of tubewells/100 ha of net cultivable land) in 2000-01: A Block Level Cross Tabulation

Sl. No.	**Category**	**Number of blocks**	**Percentage to total**
1	High ground water potential-High tubewell density	68	26.0
2	High ground water potential-Low tubewell density	113	43.1
3	Low ground water potential-High tubewell density	3	1.1
4	Low ground water potential-Low tubewell density	78	29.8
5	Total	262	100.0

Source: 3rd MI census (GOI 2001)
High ground water potential: > 5MCM of net ground water/1000 ha of cultivable land
Low ground water potential: < 5 MCM of net ground water/1000 ha of cultivable land
High tubewell density: > 20 tubewells/100 ha of net cultivable land
Low tubewell density: < 20 tubewells/100 ha of net cultivable land

Table 3a. Problems Faced and Suggestive Measures in Major Canal Irrigation Commands

Problems	**Suggestions**
Canal command	
1. *Wild flooding* 2. *Non supply of irrigation at critical stages* 3. *Lack of maintenance* 4. *Supply of more water in rainy season and less in summer* 5. *Tendency of farmers to give more irrigation* 6. Unequal distribution of water due to non- leveling.	1. *Proper maintenance of the canal system* 2. *Irrigation through channels* 3. *Selection of short duration crop varieties* 4. *Use of green manure between summer and kharif* 5. *Strict release of water as per schedule.*

Table 3b. Problems Faced and Suggestive Measures in Major Tubewell Irrigation Commands

Problems	Suggestions
Tubewell command	
1. Cultivation of long duration summer paddy *2. Cultivation of paddy in upland* *3. Follow the same crop sequence in the command* *4. Low voltage of electricity* *5. Lack of organic matter application in the field* *6. Arsenic problem in ground water* *7. Lack of coordination within the users and committee.*	*1. Spout wise crop cafeteria* *2. Reduction of seepage by lining the channels by burned clay or by use of polythene sheet* *3. Maintenance of irrigation infrastructure* *4. Not to cultivate paddy more than 50% of the command* *5. Introduction of legumes in the cropping system* *6. Selection of short duration paddy* *7. Use of organic matter* *8. Irrigation at night time.*

Technologies Developed for Efficient Water Management

For increasing the water use efficiency in agricultural systems, some technologies developed are stated below:

Surface Irrigation

A. Paddy:

I. Intense puddling with tractor drawn rotary puddler yields reduction in percolation water (5 cm during the crop growth). Table 4 shows the puddling effect on water use efficiency.

Table 4. Effect of Puddling on Water Use Efficiency of Summer Rice at Kalyani, West Bengal

Puddling operation	Irrigation No.	Total water applied (cm)	Grain yield (t/ha)	Straw yield (t/ha)	Water use efficiency (kg/ha cm)
Intense puddling	2	15	3.47	5.58	42.4
Light puddling	5	25	3.08	4.33	31.4
CD (p = 0.05)	-	-	0.29	0.53	-

II. Irrigation after three days of disappearance of ponded water during kharif season and one day in boro season reduced the water requirement by 26 and 42% respectively over the continuous submergence (Table 5).

Table 5. Effect of Intermittent Irrigation Regimes on Yield and Water Requirement of Rice at Memari, West Bengal.

Season	**Yield (t/ha)**				**Saving in irrigation water with ponding (%)**
	Continuous submergence	**Irrigation days after disappearance (DAD)**			
		1 day	**3 day**	**5 day**	
Kharif	4.67 (86)*	4.66 (73)	4.50 (68)	4.19 (63)	26 (3 DAD)
Summer	6.08 (132)	5.37 (93)	4.80 (64)	4.45 (49)	42 (1 DAD)

* figures in parentheses indicate irrigation water requirement (cm)

III. Shallow submergence of 1-3 cm up to tillaring stage, followed by deeper submergence of 5 cm up to milking stage is optimum for both productivity and water saving.

IV. Adoption of short duration variety in summer season escapes the non-availability of irrigation water due to the draw down of the ground water, particularly in tube well command area.

B. Other Crops: To minimize over irrigation, different irrigation scheduling criteria were developed for different crops as stated in Table 6.

Table 6. Different Irrigation Scheduling Criteria Developed for Different Crops

Crop	**Phenological stages**	**Moisture tension (Bar)**	**IW:CPE[§]**
Wheat	Crown root initiation, tillaring, flowering and grain filling	0.6	1.0
Potato	-	0.33 (20 cm depth)	1.2
Mustard	Branching and flowering	0.8	0.6
Groundnut	Flowering and pod development	0.6	0.6-1.0
Maize	Growth, tasseling and milking	0.55 (Vegetation), 0.35 (reproductive)	1.2
Cabbage	Growth and head development	0.6	1.5
Cauliflower	Growth and curd development	0.6	1.5
Onion	Growth, vegetation building and maturity	0.5	1.2

[§]IW:CPE = depth of irrigation water: cumulative pan evaporation

Wheat is grown in this region usually in rice-wheat cropping sequence. Due to shorter crop season, the water requirement of crops is around 30 cm. 4 irrigations each of 5 cm is found to be optimum at 1.0 IW:CPE ratio (Table 6, 7). For enhancing the water use efficiency, this crop should be sown at an early date so that the crop season may be extended. A border length of 5 cm with 90% cut off ratio is found to be optimum for higher water distribution efficiency. The optimum irrigation scheduling based on IW:CPE ratio with 5 cm depth of irrigation and total water use of other irrigated crops like oilseeds (mustard, sunflower etc), winter maize, vegetable crops, green chilies, onion, spices are given in Table 7. 20% of the total crop water demand can be saved if water table is less than 1-1.5 m and the percentage is reduced if the water table recesses to 2 m. Under constraints of irrigation water one irrigation boosting the productive level to a great extent.

An irrigation scheduling calendar (Table 8) was developed for some major crops of new alluvial zone of West Bengal. The criteria was based on IW:CPE ratio under different dates of planting.

Table 7. Yield, Irrigation Water Requirement and Water Use at Optimum Schedule of Irrigation of Different Irrigated Crops, Studied at Kalyani, West Bengal

Crop	**No. of irrigations**	**IW:CPE[§]**	**Grain yield (t/ha)**	**Irrigation water requirement (cm)**	**Total water use (cm)**	**Water use efficiency (kg/ha cm)**
Wheat	3	1.0	2.45	15	30.6	80.1
Mustard	2	0.8	1.25	10	18.5	67.6
Sunflower	4	0.8	2.29	24	24.5	93.5
Winter maize	3	1.2	3.03	25	30.3	100.0
Green chilies	5	1.2	4.96	25	32.3	153.6
Onion	3	1.2	10.45	15	33.3	313.8
Cabbage	5[*]	1.5	39.50	15	21.1	1872.1
Coriander	2	30 and 40[#]	0.69	10	30.2	22.8

[§]IW:CPE = depth of irrigation water: cumulative pan evaporation; [*]indicates IW = 3 cm; [#]denotes days after sowing (DAS)

Table 8. Irrigation Calendar for New Alluvial Zone of West Bengal, Based on IW:CPE Ratio Under Different Dates of Planting

Crop	**Date of planting**	**Days of irrigation after sowing**							
		1st	**2nd**	**3rd**	**4th**	**5th**	**6th**	**7th**	**8th**
Wheat	1st Nov.	21	47	77	100				
	15th Nov.	24	53	80	106				
	1st Dec.	27	50	75	94				
Potato	1st Nov.	7	20	33	51	69	84	98	108
	15th Nov.	5	15	29	47	64	79	91	103
	1st Dec.	5	16	34	52	67	79	90	107
Mustard	15th Oct.	23	53	89					
	1st Nov.	27	58	93					
Groundnut	1st Feb.	31	53	67	84	100			
	15th Feb.	26	47	66	79	96			
	1st Mar.	23	42	59	72	89			
Maize	1st Nov.	14	31	50	75	87	105		
	15th Nov.	17	38	62	87	104			
	1st Dec.	20	42	67	87	100			
Cabbage & Cauliflower	1st Sept.	43	63						
	15th Sept.	28	48	77					
	1st Oct.	13	20	29	39	50	64	78	
Onion	1st Nov.	14	31	50	75	87	105		
	15th Nov.	17	38	62	87	104			
	1st Dec.	20	42	67	87	100			

Technological improvements in irrigation systems have also increased production opportunities. Traditional irrigation technologies (furrow, border and flood irrigation) which involve water delivery to plants through gravitation usually resulted in substantial water losses and limited uniformity in water distribution. Modern irrigation technologies, particularly sprinkler and drip irrigation, increase water use efficiency. They have opened up opportunities to cultivation in soils with low water-holding capacity (sandy and rock soils) and to farm low quality lands and steep slopes. This technology has also enabled regions facing limited water supplies to shift from low-value crops with high water requirements (e.g. cereal) to high value crops with lower water requirements such as fruits, vegetables and oil seeds.

Pressurized Irrigation

Pressurized irrigation systems (drip, bubbler and sprinkler) have been recently introduced in agricultural production system for their high water use efficiency. At present, the area under pressurized irrigation system is very low in eastern states excepting tea cultivation. However, due to its water economy and substantial government support, its potential in water scarce and other ecologically disadvantaged areas is increasing fast. An investigation in this field has already been initiated and efforts are being made to evaluate a technology suited to the large marginal farmers of this region. The results of the experiment conducted at Kalyani on Papaya (Table 9) revealed that drip irrigation at 80% pan evaporation (PE) saved 54% of irrigation water and improved fruit yield by more than 23% compared to surface irrigation.

Table 9. Efficacy of Drip Irrigation to Papaya at Kalyani, West Bengal

Treatment	Yield (t/ha)	Irrigation water applied (cm) in non-rainy season	Saving in water (%)
100% PE*	36.2	13.8	42.5
80% PE	40.0	11.0	54.1
60% PE	38.5	8.3	65.4
Surface, IW: CPE§ = 1.0	31.2	24.0	

*PE = Pan Evaporation; §IW: CPE = Depth of Irrigation Water: Cumulative Pan Evaporation

In spite of the major support provided by the governments for promotion of pressurized irrigation system, the rate of adoption of this particular system is very meager in eastern states of the country. The possible reasons for non-adoption are i) More marginal farmers with less land holding ii) High input cost iii) Lesser period of irrigation iv) Lack of power resource v) Lesser marketing facility.

To reduce various constraints in adopting commercially available drip systems and to achieve the added advantages of drip irrigation, a modified gravity type- hand pump based drip system suited for farmers having marginal lands holding has been fabricated and evaluated at Kalyani, West Bengal for high value crops in non rainy season. In this system, a diesel drum is placed at a height of 3 m above the ground and the water is lifted by a general hand pump and the water from the barrel can be supplied to the crop regularly through drip system network. This technology is suitable for a land of 0.1 ha.

Rainwater Harvesting

Since long, efforts have been made by various organizations to harvest the rainwater through various ponds and percolation tanks in drought prone areas of West Bengal (districts of Purulia, Bankura and West Midnapore). The local people who are the users of the water for irrigation purpose are managing the water distribution. But the periodical maintenance of the tanks, cleaning of supply and distribution channels, minor repair and desiltation have been neglected causing deterioration of the efficiency of the system. Hence, there is an urgent need to rehabilitate them to their design standards and improve their performance level through farmer's participation and management.

In order to facilitate local management of the small irrigation tanks in a sustained manner, the following recommendations are suggested.

I. All irrigation tanks servicing land will be vested with the local bodies,
II. There shall be water users association (WUA) for each tank, which will operate, maintain, manage and generate income from the system,
III. The WUA will contribute to an endowment fund from the turnover of the system; and Government through *Panchayat* will provide a matching grant on 1:1 basis,
IV. The income thus generated will be utilized by WUA for only operation, maintenance and management of the system.

Epilogue

From the work reviewed on water management, it has been very conclusively established that there is a lot of scope for improving water use efficiencies that can be exploited to enhance productivity. However, there are several aspects for which there is a need to conduct detailed investigations and generate systematic information. They are:

- Appropriate water management practices to achieve higher water use efficiency for new crops and cropping systems in rabi-summer season.
- Standardization of consumptive water use for important cropping systems in the broader perspective of sustainability of production systems and water resource use.
- Efficient rain water and crop management system under variable soil type and rainfall with a view to achieve appropriate partitioning of water for crop production and ground water recharge.
- Appropriate and efficient water use technology for commercial cropping systems with emphasis on fruits, flowers and vegetables in small farms.
- Farmers participatory models for water use technology under irrigated and rainfed production systems.
- Encouragement of watershed management.
- Development of database on water resources availability and utilization.
- Multiple uses of water

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IMPLEMENTABLE TECHNOLOGIES ON MORE CROP AND INCOME PER DROP OF WATER

B. Bhaskar Reddy* & R. Vijaya Kumari*

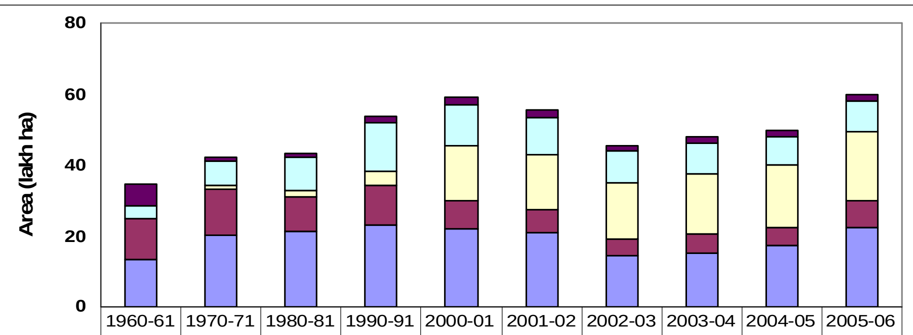
Agriculture is the lifeline of Andhra Pradesh's economy. It contributes over a third of the State's GSDP and provides a livelihood for over 70 per cent of its population. Andhra Pradesh is characterized by varied climate, water resources and soil that make it possible to grow a variety of crops, and a large coastline that facilitates exports. The estimated surface and ground water resources account for about 108 BCM, of which about 62 BCM (58%) is being utilized for drinking, agriculture, industry and power generation. Among the four sectors agriculture is the major consumer (>98%) of water (Table 1).

Table 1: Water utilization by various sectors in Andhra Pradesh (Million Cubic Meters)

	Present Utilization (2000)	Need by 2025
Drinking Water	601	3468
Irrigation	64252	108050
Industries	288	1445
Power Generation	28	56
Total	65169	114101

Source: A P Water Vision, 2003 - Water Conservation Mission, Govt. of Andhra Pradesh

Andhra Pradesh has been subdivided into 1229 ground water basins, of which 20 per cent area is under projects with 60 per cent adequate ground water resources and limited exploitation. In the remaining 80 per cent under non-project area, the ground water availability is limited (40%) and exploitation is maximum**.** The increase in population and demand for food has led to over exploitation of ground water resources. The gross irrigated area by different sources in Andhra Pradesh from 1960 to 2005 presented in Fig 1 clearly indicates significant rise in the area under tube well irrigation over last three and a half decades in the State. The gross and net irrigated area under different sources were about 60 and 44 lakh hectares respectively during 2005-06.



	1960-61	1970-71	1980-81	1990-91	2000-01	2001-02	2002-03	2003-04	2004-05	2005-06
Other Sources	6.33	1.3	1.11	1.92	2.23	2.07	1.51	1.57	1.79	2.07
Other Wells	3.57	6.83	9.34	13.67	11.59	10.45	8.78	8.72	8.13	8.37
Tube Wells	0	0.94	1.91	3.93	15.34	15.73	16.01	17.01	17.5	19.59
Tanks	11.51	12.85	9.77	11.07	7.98	6.34	4.54	5.38	5.15	7.62
Project Canals	13.31	20.31	21.29	23.11	22.02	20.89	14.52	15.13	17.3	22.31

Fig 1: Gross irrigated area by different sources in Andhra Pradesh (lakh hectares)
Source: Directorate of Economics and Statistics, Govt. of Andhra Pradesh

*Acharya N.G. Ranga Agricultural University, Rajendranagar, Hyderabad - 500 030

Harnessing Water Resources

Development of water resources is critical to several aspects of the State's development. Greater investment in the irrigation sector during successive five-year plans increased cropped area under irrigation and productivity of the land, leading to a substantial impact on agricultural and industrial growth, income and employment. However, in a predominantly agricultural economy like Andhra Pradesh, achieving the levels of growth targeted will not be possible without considerable emphasis on better water resource management. This will require the following approach: realizing the maximum irrigation potential of the State; improving the efficiency of the existing irrigation network and better managing water resources.

Sustainable development of rural areas involve conservation of land and management of water resources. Increasing pressure of the ever-growing human and cattle population, increased living standards and the concomitant economic activities are exerting tremendous pressure on the finite natural resources. Due to lack of advance planning and non-judicious/indiscriminate use of natural resources, ground water levels are getting depleted and lands are getting either degraded or turning into wasteland. Andhra Pradesh Government has launched a massive watershed program for development of all degraded and waste lands during 1997 with the aim of treating 100 lakh ha of land. The Government of Andhra Pradesh has constituted ***Water Conservation Mission during 2001*** with the prime objective of conservation and utilization of water on a sustainable basis. The plans and programs of these line departments working directly or indirectly for conservation and utilization of water are clustered together into a single programme christened as ***Neeru - Meeru (Water and You)*** with the motto promoting of water conservation on a mission basis.

The following structures have been constructed to create the additional filling space and recharge of additional ground water.

- Continuous contour trenching, continuous peripheral contour trenching, staggered trenching.
- Gully control works.
- Check dams and percolation tanks, farm ponds, bunding, sunken pits, feeder channels, supply channels.
- Desiltation of tanks, restoration of tanks etc.

In addition to these, certain districts are involved in the revival of age-old traditional water conservation practices such as:

- The revival of age-old chain of tank systems in Srikakulam district.
- Conversion of dried up dug wells as recharge pits through simple diversion drain techniques and
- Installation of low cost sunken pits in Medak district as recommended by the Technical Committee wing of the WCM.

Broadly, the measures for increasing productivity of water consumed in agriculture are as follows

- Agronomic Practices
    - — Crop varietal improvement
    - — Crop substitution
    - — Improved cultural practices

- Water Management Practices
  - — Improved water supply management.
  - — Improved on-farm water management.
  - — Deficit, supplemental and precision irrigation.
  - — Reallocating of water from lower- to higher-value uses
  - — Water recycling

All the aforesaid technologies have to be adopted on scientific watershed basis with the aim of sustaining hydrological and ecological balance of region / area.

Watershed Development and Management

Scientific micro watershed development programme helps in conserving every drop of water received through the rain. It increases the utilizable water resources, prevents the soil erosion and mitigates the hazards of drought.

Water Harvesting

Rainwater harvesting has to be prioritized based on the hydrogeology and socio-economic conditions. It has to be implemented in a river basin or sub-basin where the water outflows unutilized either through the surface or through the ground water aquifer.

Adarsha Watershed in Kothapally, Rangareddy district is one of the watersheds in Andhra Pradesh where rain water harvesting has been implemented successfully. Soil and water conservation measures implemented by farmers in individual fields (Wani et al, 2002) were broad-bed and furrow (BBF) landform and contour planting to conserve in situ soil and water, use of the tropicultor for planting, fertilizer application and weeding operations, field bunding (38 ha), and planting *Gliricidia* on field bunds to strengthen bunds, conserve rainwater and supply nitrogen (N)-rich organic matter for in situ application to crops.

Farmers obtained 250 kg more pigeon pea and 50 kg more maize per hectare using BBF on medium-depth soils than from the flat landform treatment. Furthermore, even on the flat landform treatment farmers harvested 3.6 t maize and pigeon pea using improved management options compared to only 1.72 t maize and pigeon pea grain from their normal cultivation practices.

Improved Ground Water Levels: There was a significant improvement in the water levels of most wells, particularly those located near check-dams. Due to additional ground water recharge, a total of 200 ha in post-*kharif* season and 100 ha in post-*rabi* season, mostly vegetables, were irrigated during the 2002/03 cropping season. Based on three years (1999–2001) of observations on levels in open wells, the estimated average rise was 4.15 m. Thus, the average contribution of the seasonal rainfall in the watershed could be estimated at approximately 27% of the seasonal rainfall (assuming the specific yield of the aquifer material as 4.5%) (Pathak et al, 2002).

Improved Land Cover and Vegetation: The land cover and vegetation density in Adarsha watershed was studied using satellite images to assess the impact of various interventions on these parameters. The IRS-1C and -1D LISS-III images of April 1996 and April 2000, and the NDVI (Normalized Difference Vegetation Index) images generated from these revealed an increase in vegetation cover from 129 ha in 1996 to 200 ha in 2000 (Dwivedi et al, 2003).

Increased Productivity: Farmers evaluated improved crop management practices (INM, IPM and soil and water management) together with researchers. With improved technologies farmers obtained high maize yields ranging from 2.2 to 2.5 times the yield of sole maize (1.5 t ha^{-1}) in 1998. In the case of maize intercropped with pigeon pea, improved practices resulted in a four-fold increase in maize yield (2.7 t ha^{-1}) compared with farmers' traditional practices where the yields were 0.7 t ha^{-1}. Improved practices increased sorghum yield three-fold within one year while the yield of intercropped pigeon pea increased five times in 2000 (ICRISAT, 2002).

Of all the cropping systems studied in Adarsha watershed, maize/pigeon pea and maize/chickpea intercropping systems proved to be most beneficial. Farmers could gain about Rs. 16,506 and Rs. 19,457 from these two systems, respectively. Sole sorghum, sole chickpea and sorghum/ pigeon pea intercropping system also proved to be beneficial, whereas sorghum, maize and mung bean traditional systems were significantly less beneficial to farmers. Cotton grown with traditional management practices resulted in a net loss (ICRISAT, 2002).

Rice fallow pulses / maize in Krishna delta of Andhra Pradesh during rabi season is a boon to the farming community through improving net returns and efficient use of soil moisture / irrigation water. Intercropping / multistoried cropping systems increased the land equivalent ratio, net income and resource use efficiency particularly soil moisture and solar radiation. Introduction of soybean / cotton in black soils and maize, pulses and oilseeds in red soils in tank commands improved cropping intensity and water use efficiency and net income.

Changes in Cropping Pattern: Analysis of prevalent cropping systems, their area and previous history before the watershed management intervention provides insight into the way the watershed management approach has benefited farmers. Kothapally was predominantly a cotton-growing area prior to project implementation. The area under cotton was 200 ha in 1998. Maize, chickpea, sorghum, pigeon pea, vegetables and rice were also grown.

After 4 years of activities in Adarsha watershed, the area under cotton cultivation decreased from 200 to 80 ha (60% decline) with simultaneous increases in maize and pigeon pea. The area under maize and pigeon pea increased more than three-fold from 60 to 200 ha and 50 to 180 ha, respectively within four years. The area under chickpea also increased two-fold during the same period (ICRISAT, 2002).

Farming Systems Approach

Integration of sheep production in groundnut farming system offers gainful employment in rainfed areas of Anantapur district. Groundnut cake is the most important byproduct used as protein source and cattle feed. Groundnut haulms are used for feeding cattle and sheep. The major food crops and various possible farming systems of different agro-climatic zones of Andhra Pradesh are presented in Table 2.

Table 2: Major Food Crops and Various Possible Farming Systems of Different Agro-Climatic Zones of the Andhra Pradesh (M. D. Reddy, 2005)

Agro climatic zone	**Major food crops**	**Dairy**	**Sheep and goat**	**Backyard poultry**	**Fishery**	**Api-culture**
North Coastal	Rice, pulse, ragi, sesame, sugarcane, cashew nut	Cattle, buffalo	Sheep, goat	Backyard poultry	Inland coastal	Api-culture
Krishna-Godavari	Rice, maize, pulse, sugarcane, coconut, cotton, chillies	-do-	Sheep in Prakasam	-do-	-do-	-do-
South	Groundnut, rice, ragi, jowar, pulses, cotton, sunflower	-do-	Sheep	-do-	Inland	-do-
Scarce rainfall	Groundnut, rice, safflower, jowar, pulses, cotton	-do-	Sheep	-do-	Inland	-do-
Southern Telangana	Groundnut, castor, sunflower, pulses, rice, jowar, cotton	Buffalo, cattle	Sheep, goat	-do-	Inland	-do-
Northern Telangana	Rice, maize, jowar, pulses, cotton, groundnut, chillies, sugarcane	Buffalo, cattle	Sheep, goat	-do-	Inland	-do-
High altitude and tribal zone	Rice, maize, bajra, jowar, sugarcane, pulse	Buffalo	Sheep, goat	-do-	Inland	-do-

Water Management Techniques for ID Crops

Irrigation Methods

Irrigation can be applied to crops by adopting any of the several methods (check basin, border strips, furrow, sub-surface, sprinkler, drip) of water application. In many cases more than one method may apparently seem to be obvious, whereas in some cases, the choice of a particular method may appear to be obvious. The general guidelines for the selection of appropriate irrigation method are described in Table 3.

Surface Method

The surface method of irrigation covers more than 99 % of the irrigation area. Properly designed and operated surface irrigation is one of the most simple, efficient and cost effective methods of irrigation, if soil characteristics and topography permit its feasibility. Depending on the system followed for the distribution of water over the field, surface irrigation is broadly classified into three categories, i.e., border strips, check basins and furrow methods of irrigation.

Border Strips: Proper grading and leveling with maximum earthwork gave high application and distribution efficiency as compared to undulating topography.

Table 3: General Guidelines for Selection of Irrigation Methods (Singh, 1996)

Method of irrigation	Soil texture	Infiltration rate	Land topography and slope (%)	Stream size (litres/sec)	Crops
Check basin	Light or Heavy	0.5-10	Leveled less, less than 0.1	Large, more than 15	All crops except those on ridges and susceptible to water logging
Border strip	Medium	1-2	Uniformly graded, 0.1-3.0	Any more than 12-15	All crops
Furrow	Light to Moderate	0.5-2.5	Moderate 0.3-3.0	Small, more than 12	Row crops and vegetables
Sprinkler	Very light	2.5-20	Rolling and undulating (sand dunes)	Any, more than 5	All crops except rice and jute
Drip	Light to heavy soils	0.5 or more	Level to undulating	Any, more than 5	Widely spaced vegetable and fruit crops

Check-Basins: They are relatively leveled, square or rectangular plots but length: width ratio not exceeding 4 : 1. Checks are generally preferred over coarse textured and very heavy soils without land degrading by the farmers over borders, while borders may facilitate mechanized cultivation and better surface drainage.

Furrow Method: This method is particularly useful for soils that crust on irrigation, exhibit low infiltration rate, with high salt concentration or need surface drainage. Water in furrows moves both laterally and vertically to moisten the ridges and sub soils. The length of the furrow generally increases with the increase in irrigation depth, fineness of soil and slope up to certain limits (3%). Furrow irrigation involves higher labour costs, but is generally more efficient than the border and check methods.

Furrow method involves water application as small running streams in between the ridges (crop rows). Water infiltrates into the soil and spreads laterally between the crop rows. Both large and small irrigation streams can be used by adjusting the number of furrows irrigated at any one time to suit the available flow. Furrows act as irrigation cum drainage facilities. It is useful to dispose the heavy run off from rainfall rapidly. Furrow irrigation is amenable for various crops like onion to cotton. The furrow length is 5-6 m in lift irrigated areas.

AlternateFurrow Irrigation: Furrows formed within check basin or border methods are used for alternate furrow irrigation by alternating the irrigation between two Furrows. At a point of time one set of furrows, say the odd numbers are irrigated. It is alternated and the even numbers are irrigated during next irrigation. Alternate furrow irrigation is water saving accounting for 35-40 percent without yield reduction. Seasonal rains would overcome the stress condition. There is also risk of marginal reduction in yield due to rainless condition but not failure of crop.

Skip Furrow Irrigation: In case of skip furrow irrigation, one set of furrows either odd or even numbers are permanantly skipped. There is labour saving since one set of furrows are permanantly skipped. There is significant yield reduction in this method in cotton and other crops.

Paired Row Furrows: In paired furrow methods, instead of even spacing between furrows, two rows are formed closely in pair and another two rows are formed wider apart. This enables two close rows to get irrigated. The wider spaced areas between two sets get unirrigated. This method can be adopted in wide row crops like maize, cotton, etc. (K. Anand Reddy et al, 1978).

Paired Row or Double Row Furrows: Normally broad ridges are formed and the crops are sown on both sides of the ridges maintaining the normal spacing of crops between rows and in the rows. This method is highly useful for close spaced crops where the spacing is less than 60 cm. Also, this method is useful for different soil textured groups. Paired row furrows are adopted for saline and sodium soils to avoid salt concentration in the root zone. In close spaced crops like sorgum, groundnut, gingelly, greengram and blackgram, paired row furrows are highly successful.

Overhead Irrigation Methods

Traditional irrigation techniques such as flood and furrow irrigation, rely on gravity to deliver water to crops. With furrow irrigation, water is diverted from a ditch or other water transport system, to flow down a furrow between rows of crops. With flood irrigation, water is similarly diverted but in a sheet of water over a slightly graded section of land between widely placed levies. Both methods require a substantial volume of water over a short period of time. To get water from one end of the field to the other, a farmer must use more water than is needed for plant consumption.

Modern irrigation technologies, such as sprinkler and drip irrigation, use energy to pump water through closed systems to the crops. These technologies allow more frequent irrigation with smaller volumes of water. The distribution of water is more uniform than with gravity irrigation, less water is lost to evaporation, there is deep percolation and runoff, and soil erosion is reduced. With more uniform and timely application of water, more crops can be produced with less water.

Sprinkler Method: Sprinkler method ensures high degree of water control and enables judicious utilization of even small water flow on undulating and shallow soils. It saves 10-16 % land than that other surface methods consume in channels and ridges and can give overall irrigation efficiency as high as 80-82% as compared to 30-50% in surface irrigation. Sprinkler irrigation can be adopted for almost all crops and on most soils. The method not only ensures the highest water economy (up to 50%) but also provides good irrigation. It has been observed that vegetables, groundnut, forage crops, tea and coffee gave higher yields, good quality produce and greater water economy when irrigated by sprinklers (Rao, 1994; Agarwal et al., 1997)

Drip or Trickle Irrigation: In this case only a part of soil in the vicinity of plant roots is wetted and kept close to field efficiency (90-94%) but it provides ideal moisture regime for high yield and quality produce, especially in vegetables and horticultural crops. Physically, the system is adoptable to a wide range of soils, topography, water quality and crops (Table 4).

Table 4: Comparison of Surface and Drip Methods of Irrigation in Field and Vegetable Crops (Rao, 1994)

Crops	Yield (q/ha)		Yield increase (%)	Water applied (cm)		Water saving (%)
	Surface	Drip		Surface	Drip	
Cotton	23.0	29.5	27.0	89.5	42.0	53.0
Tomato	164.0	171.2	5.0	29.7	20.8	27.0
Brinjal	280.0	320.0	17.5	90.0	42.0	55.8
Bottle-gourd	154.3	214.7	13.5	24.5	11.5	52.1
Ridge-gourd	1582.8	1667.0	5.0	195.0	78.4	59.8
Cabbage	195.8	180.0	23.4	66.0	23.3	59.5

Conjunctive Use of Irrigation Sources

Of the three irrigation sources identified, only ground water source satisfies the conditions required for ideal irrigation viz., with respect to time and quantity. But there are other disadvantages with this system. One is that, it is costly to develop and to maintain a ground water source. Second, its total potential is small and area cannot be extended beyond its capacity. With the use of only the well as the irrigation source, the cropped area gets limited and the irrigation cost is high. Such options are fixed in those areas where the ground water is the only source of irrigation. There are certain other locations wherein one can have the surface irrigation source (river canal / tanks) and also it is possible, to develop ground water source. Under such circumstances it is to the advantage of the farmer to adopt a system of conjunctive use of the two irrigation sources.

Surface water is comparatively cheap and abundant, ground water is costly and limited. By a judicious combination of these two sources, a farmer can achieve considerable production increase. Irrigation management can be done in time and in quantities adequate for the crop stage. The deficiencies on the management of the surface irrigation systems could be offset by adopting conjunctive use method. When the surface water is available the farmer can use it and when it is not available, he can use the ground water. In a conjunctive use system of irrigation, an amalgamation of the advantages of both the surface and ground water irrigation system is obtained.

Water Management in Rice

In the State, rice is the predominant crop consuming maximum (>80%) irrigation water, covering 64 per cent of irrigated area (Table 5). Any technology aiming at reduction in its water use will have greater implication on water availability for agriculture and other uses.

Table 5: Crop-wise Area Irrigated by Different Sources in Andhra Pradesh (2005-06)

Crop	Area irrigated in '000 hectares						% of Irrigated area under the crop to the total irrigated area
	Canals	Tanks	Tube Wells	Other Wells	Other Sources	Total Irrigated	
Paddy	2000	704	709	267	165	3845	64.1
Jowar	15	1	16	2	1	35	0.6
Bajra	N	N	15	2	1	18	0.3
Maize	36	10	119	93	2	260	4.3
Ragi	N	1	7	4	N	12	0.2
Chillies	20	N	51	46	10	127	2.1
Turmeric	4	1	35	27	1	68	1.1
Sugarcane	69	28	258	37	8	400	6.7
Cotton	23	3	59	120	3	208	3.5
Groundnut	22	6	166	81	6	281	4.7
Sesamum	1	N	8	3	2	14	0.2
Sunflower	16	3	103	18	1	141	2.4
Onion	N	N	21	9	N	30	0.5
Tobacco	1	N	25	4	3	33	0.6
Other Crops	24	5	367	124	4	524	8.7
Total Area Irrigated	2231	762	1959	837	207	5996	100

Note: N : Negligible
Source: Directorate of Economics and Statistics, Govt. of Andhra Pradesh.

Low Water Technologies for Rice

- Aerobic rice
- Wet seeded rice
- Rotational irrigation practices for transplanted rice

Rotational Irrigation to Transplanted Rice

Continuous shallow submergence is not necessary for high yields. Instead, irrigation at soil saturation/rotational irrigation (5–10 cm) gave comparable yields, but reduced water need of the crop. Cyclic submergence (5 > 0 cm), maintenance of near saturation condition during kharif (low evaporative demand) and phasic submergence during rabi near saturation up to active tillering and shallow submergence (5 + 2) cm from active tillering to physiological maturity and withholding irrigation up to harvest (medium evaporative demand) and continuous shallow submergence during summer (high evaporative demand) is found optimum for rice.

In areas of limited water supply, varieties of short duration have been found to be more suitable. Field studies carried out under Water Management and Salinity scheme of ICAR (1974) suggest that even among the high yielding varieties, those of short duration were better and had high water use efficiency compared to varieties of longer duration.

Under deficit water supply thorough puddling, perfect land leveling, maintenance of field and guided bunds, cross bunding across drainage channels besides rotational water supply at wider intervals (5-15 days) at less critical stage and adequate water supply at critical stages improve irrigation water use. Success of rotational water supply can be ensured through close co-ordination of different agencies, farmers and farmer's organizations engaged in irrigated agriculture. The success stories include crisis management of 1986 in Nizam sagar, 1987 in Krishna delta, 1995 under Sri Ram Sagar Project, 2000-01 in Godavari delta, and 2001-02 under Upper manair project.

Dry Seeded Rice / Aerobic Rice

In areas where water is released late through canals/tanks including tail end areas, high intensity rain during one or other crop growing stages cause land submergence. In these lands, there is no possibility of growing crops other than rice. Under these circumstances, establishment of dry seeded rice in low land fields is followed in accordance with the local rainfall pattern to some extent under tank and canal irrigated deltaic areas. In these lands, growing of dry sown paddy under rainfed conditions for 1-2 months and converting it to wet as and when canal/tank water is released became an alternative in some areas to utilize rainfall effectively. This practice saves about 350 mm of water by avoiding nursery, main field preparation though the crop yields are little less than transplanted rice. The information available on aerobic rice indicates that the crop yields of 3-6 t/ha can be obtained in different regions. The dry sowing and converting it to wet is practiced in some parts of Nellore – Naidupeta, Guduru, Sullurpeta; Kurnool – KC Canal command area, North Coastal – Vizianagaram and Srikakulam and Telangana – Tankfed commands and high rainfall regions of Adilabad, Karimnagar, Warangal, Khammam (Godavari basin).

Through dry seeding technology (Aerobic rice) combined with other crop management techniques like supplementary irrigation and proper fertilization, it is now possible to grow improved varieties like Erra mallelu, Jagtiala Sannalu and Polasa prabha using less water but obtaining higher yields. The short duration variety Varalu required 710 mm of water and medium duration variety Polasa Prabha required 1002 mm of water including effective rainfall which was 265 and 324 mm respectively in short and medium duration varieties.

Crop Diversification

In the face of shrinking natural resources and ever increasing demand for larger food and agricultural production arising due to high population and income growths, agricultural intensification is the main course of future growth of agriculture. Because of changing rainfall pattern over years, ground water depletion and hike in labour wages, the existing cropping pattern may be economically not viable. It is the time to critically re-design alternative cropping pattern based on agro climatic zone and this must be demonstrated in the farmers' holdings in order to effectively utilize the natural resources and also to improve and stabilize the production and profitability.

Crop diversification -

- From *Low value to High value crops;*
- From *High water requiring crops to Low water requiring crops;*
- *From Mono crop to Multiple / Mixed crop;*

- From *Crop alone to Crop with Crop-livestock-fish-apiculture (Farming systems approach);*
- From *Agriculture Production to Production with Processing and Value Addition*.

At Hyderabad, a marginal farmer with 0.5 ha cotton and maize + pigeon pea systems recorded the B:C ratio of 3.47 and 4.43 respectively. One milch animal on an average gave an additional net benefit of Rs.380 per year. At CRIDA, the horti-pastoral system *Cenchrus / Stylo* in rainfed guava and custard apple, the *Cenchrus* yielded dry forage of 7 tones / ha with 17.5% of crude protein during the first year, while stylos recorded the yield of 5.6 tones of dry fodder during the second year of plantation. In Ber based agri-horti system pearl millet + pigeon pea (Solapur), pigeon pea + blackgram (Rewa), castor (Dantewada) and cluster bean (Hyderabad) showed promising results in rainfed environment. Ber on an average gave 40 kg fruits / tree along with the 100 kg of horse gram and 450 kg of cowpea cultivated in interspaces (Osman *et al.,* 1989). Radhamani (2001) reported the additional employment gains (314 man-days/year) through integrated farming system with crop + goat under rainfed vertisols.

Cultivation of vegetables, fruits and spices under crop diversification project has brought a big change in life and livelihood of farmers, who find farming of high value crops more rewarding than traditional rice farming at some locations. High value crops are less time-consuming, but returns are three to four times bigger than that of paddy. A farmer earns good amount of money from potato, tomato, chilli and vegetables grown on the half of his less than an acre of land.

Summary and Conclusion

Today water management is the universal burning issue requiring immediate attention right from policy makers to the stakeholders. The traditional water harvesting, storage structures, their distribution channels, etc reflect the immense attention paid by our ancestors at the beginning of civilization itself. Hence, the water management is not a new subject for the human kind. However, the reason behind its present importance is an outcome of human actions undertaken against nature over long years.

The increase in population and demand for food has strong positive correlation indicating the need to harness the existing water resources. In present day context under WTO regime, there is need for Indian government to frame and implement appropriate policy measures for increasing the water potential, its use efficiency and thus the net income of the large sector of our economy i.e., agriculturists. As an endeavor, the year, ***2007*** had been declared as ***World Water Year*** with a vibrant slogan of ***'More crop and income per drop of water'***.

Revitalization of traditional water harvesting and storage structures besides constructing new ones; conjunctive use of water resources; adoption of yield increasing and on-farm water saving technologies like crop varietal improvement, crop diversification, intercropping, multi-storied cropping, rice fallow pulses / cereals with minimum tillage, aerobic rice, wet seeded rice, waste water use, modern irrigation methods i.e., drip and sprinkler methods; watershed development and management and afforestation were found to be most successful technologies in Andhra Pradesh, which needs encouragement for implementation in wider extent.

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Artificial Recharge of Ground Water Advisory Council

Artificial Recharge of Ground Water Advisory Council has been constituted under the Chairmanship of Hon'ble Minister of Water Resources, Government of India with the objective to popularize the concept of Artificial Recharge of ground water amount all stakeholders and its adoption.

OBJECTIVE:

The main objective of setting up Artificial Recharge of Ground Water Advisory Council is to popularize the concept of Artificial Recharge among all stake holders and its adoption.

Terms of Reference:

- Prioritizing areas
- Area specific technology
- Co-ordination among various Central and State organizations.
- Co-ordination among NGOs, Industries/stake holders
- Periodic review of action taken by Centre & States
- Power to set up sub-committee – function / area based
- Funding strategies including private participation
- Role of Stake holders
- Creating awareness / education / capacity building
- R & D – especially of development of low cost technology

Composition:

A Permanent members – 12

• Minister of Water Resources	-	Chairman
• Minister of State for Water Resources	-	Deputy Chairman
• Secretary, MoWR	-	Member
• Advisor, Planning Commission	-	Member
• Chairman, CWC	-	Member
• Chairman, CGWB	-	Member
• Chairman, CPCB	-	Member
Representative from		
• Ministry of Rural Development	-	Member
• Ministry of Urban Development	-	Member
• Ministry of Agriculture	-	Member
• Ministry of Environment & Forest	-	Member
• Commissioner (GW), MoWR	-	Member Secretary

B Member on rotational basis (for 2 years) – 7
Secretary in charge of Water Resources of the States/UTs

- Eastern States
- Western States
- Northern States
- Central States
- Southern States
- North-eastern States and
- Hilly States/Islands/UTs

C Subject experts/Farmers' representative – 6

D Representative from financial institutions – 2

National Bank for Agriculture and Rural Development
Rural Electrification Corporation Ltd.

E Industries / Public undertakings – 5

- FICCI
- CII
- ASSOCHAM
- ONGC and
- Coal India Limited

F Representative from NGO's – 5

The first meeting of Artificial Recharge of Ground Water Advisory Council was held on 22.7.2006. Decisions taken during the meeting and follow up actions are as follows.

I Need for Regulatory Measures:

1. To pursue the states which have not yet enacted suitable legislation to regulate ground water development and management and to organize Chief Minister's conference to discuss the issues.
2. To prioritise action for recharge and rainwater harvesting in all 1065 blocks categorized as "over-exploited"/"critical" and "semi-critical" by CGWB
3. To prioritise the work of assessment of ground water availability and possibility of artificial recharge in 31 districts, which have been indentified as farmer distress hot spot districts.
4. To set up a sub-committee to work on policy for water for industries, which provides the frame work for regulation as well as incentives for economic use for large users of ground water.
5. To endorse the recommendation of the national commission on Farmers that crops like ragi, bajra, jowar and pulses that utilize less water, and are grown by farmers in rainfed areas could be made part of the public distribution system.
6. To develop separate technologies for recharge, specifically for urban areas.
7. To frame strategies for wider and more effective dissemination of available information of CGWB to the user level.

II National Ground Water Congress

1. To organize a "National Ground Water Congress" once a year in order to facilitate the information sharing with govt. agencies, NGO's, industries and academia.
2. To institute an annual award for outstanding village community working on *Pani Panchayat* and to present during congress.

III Finalization of Member under Category (B) of the Resolution

Secretaries' in-charge of Water Resources of the following states were nominated by the Advisory Council for inclusion as members on rotational basis for period of two years.

1. West Bengal
2. Rajasthan
3. Punjab
4. Madhya Pradesh
5. Karnataka
6. Meghalaya
7. J & K

Advisory council suggested that there should be a separate representation of the island states in view of specific problems faced by them and recommended nomination of secretary in-charge of water resources of Anadaman & Nicobar islands as a member of the Advisory council.

Follow up action on decisions taken in the first meeting of artificial recharge of ground water advisory council held on 22.07.2006.

Sl. No.	Action Point	Action Taken
1.	CGWB to prioritize action for recharge in all 1065 over-exploited critical/semi critical blocks	Directive issued by Member Secretary, CGWA under section 5 of Environment (Protection) Act, 1986 for adoption of Artificial Recharge to Ground Water & Rain Water Harvesting to concerned States.
2.	Completion of work in 31 districts identified as 'farmers distress hot spot' on top priority	• District wise reports on assessment of ground water availability and possibility of artificial recharge have been prepared for mitigating the farmers' distress due to ground water related problems and have been submitted to the Ministry. • Preparation of block-wise information booklets for dissemination is under progress.
3.	Need to regulate large users of ground water particularly industrial users	Draft report by the sub-committee under the chairmanship of AS (WR) constituted for the purpose has been submitted.
4.	Need to integrate modern recharge technologies with traditional water harvesting technologies/need to develop separate technologies for recharge specifically for urban areas.	Regional Directorates have been advised to update area-specific literature for Artificial Recharge and Rain Water Harvesting in Rural and Urban areas. As regards integration of modern recharge techniques with community managed traditional water harvesting techniques, two areas have been identified for studies namely Vented Dam, South Kanadda district, Karnataka and tanks of Burhanpur, Khandawa district, Madhya Pradesh. The study regarding vented dam in south Kanadda district, Karnataka has been taken up AAP 2007-2008.

5.	National Ground Water Congress	National Ground Water Congress is scheduled to be held on 11th September, 2007 at Vigyan Bhawan, New Delhi.
6.	More Crop and Income per Drop of Water	Draft report by the sub-committee under the chairmanship of Dr. M.S. Swaminathan constituted for the purpose has been submitted.
7.	Nationwide Campaign for Recharge	Media Plan for nationwide campaign for recharge is under preparation in consultation with MOWR
8.	Linkage with major National Programmes	---

Three Sub-committee mentioned below, constituted as per the decision taken in the first meeting of the Advisory Council, have submitted their reports

1. Sub-committee on "Policy for Water for Industries"

A sub-committee on 'Policy for Water for Industries" with the following members has been set up to suggest a policy for water for industries which provides the framework for regulation as well as incentives for economic use for large users of ground water.

1.	Additional Secretary (WR)	Chairman
2.	An Officer to be nominated by Ministry of Environment & Forest	Member
3.	An Officer to be nominated by Ministry of Commerce and Industry, D/o Industrial Policy and Promotion	Member
4.	Mr. R. A. Lakhotia*	Member
5.	Mr. Shanker Raja Ram*	Member
6.	Member, CGWB	Member-Secretary
	(*as nominated by the CII)	

Under the chairmanship of the Additional Secretary (WR), four meetings of the sub-committee to work on the policy for water for industries were held and the report of the sub-committee has been finalized.

The report of the sub-committee has been circulated for comments / observations to Dr. M. S. Swaminathan, Chairman, M. S. Swaminathan Research Foundation; Dr. Kirit S. Parikh, Member, Planning Commission, Ms. Sunita Narain, Director, Centre for Science and Environment, Shri Ajay Dua, Secretary, DIPP and Dr. Montek Singh Ahluwalia, Deputy Chairman, Planning Commission.

2. Sub-committee on "More Crop and Income per Drop of Water"

During the inaugural address, Hon'ble Prime Minister of India, mentioned that "we have to minimize our water use – invest in science and technology to ensure that we can grow crops which use less water. In other words, find ways of valuing the crop per drop". To implement the suggestions of the Hon'ble Prime Minister, the council constituted a sub-committee under the chairmanship of Dr. M. S. Swaminathan, which held two meetings to prepare a report on "More Crop and Income per Drop of Water".

The sub-committee has drawn representatives of Ministry of Agriculture, Ministry of Rural Development, National Fishery Board, CGWB, CWC, CII and Agricultural Scientists from IARI, CRIDA, CAZRI, ICRISAT and State/ Central Agriculture Universities/Institutes.

The report highlights the implementable action plans incorporating technologies along with their economics. The steps that can be taken for rabi crops have been highlighted so that action can begin from ensuing rabi season itself.

3. Sub-committee on "Wider Dissemination of Information and Know-how"

A sub-committee has been set up with the following members to chalk out strategies for wider dissemination of information and know-how on water harvesting and artificial recharge.

1.	Sh. Sunita Narain	Chairperson
2.	Sh. Anna Hazare	Member
3.	Sh. Rajinder Singh	Member
4.	Ms. Rohani Nilekani	Member
5.	Sh. Achyut Das	Member
6.	Member, CGWB	Member
7.	JS (Administration), Ministry of Water Resources,	Member
8.	One media person to be recommended by Press Council of India	Member

Under the chairmanship of Ms Sunita Narain, the first meeting of the sub-committee was held on 18 September, 2006 and the report prepared outlines the existing status of information available and what action needs to be taken for wider dissemination in order to promote the idea of water harvesting and artificial recharge.

The second meeting of Artificial Recharge to Ground Water Advisory Council is to be held on 12 September 2007 at Hall A, Vigyan Bhawan Annexe, New Delhi to discuss the various agenda as well as to approve the reports prepared by the above three sub-committees.

BHOOMIJAL SAMVARDHAN PURASKAR
& NATIONAL WATER AWARD

for innovative practices of
Ground Water Augmentation through Rainwater Harvesting and Artificial Recharge

1. Preamble

Water is an essential and vital component of our life. The fast pace of urbanization and industrialization has put a lot of stress on water sources. The dependence on ground water for these supplies is increasing alarmingly of late, since ground water is available at the point of requirement and also directly under the control of the user. This has led to uncontrolled withdrawal of groundwater resulting in the decline of ground water levels in certain pockets of the country.

Ground Water is viewed as the common pool resource. Hence, it is necessary that this resource is protected by promoting sustainable use through technically sound management practices. The natural recharge of ground water has been substantially reduced in many areas due to human interference. It is unable to keep pace with excessive withdrawal in many areas. There is thus the need to augment ground water resources by suitable interventions to facilitate more recharge and also to prolong recharge period beyond monsoon season. The availability of source of water and favourable hydrogeological conditions are vital for the successful implementation of artificial recharge schemes.

The Bhoomijal Samvardhan Puraskar and National Water Award have been launched with an objective to encourage the Non-Governmental Organizations (NGOs) /Gram Panchayats/ Urban Local Bodies (for population up to 1 lakh) for adopting innovative practices of ground water augmentation by rainwater harvesting and artificial recharge through people's participation in the targeted areas resulting in ensuring the sustainability of ground water resources and development of adequate capacity amongst the stakeholders.

2. Eligibility Criteria

The Puraskar/Award is open to all registered NGOs, Gram Panchayats and Urban Local Bodies who have achieved excellence in the field of ground water management by adopting measures of rain water harvesting and artificial recharge to ground water. The selected NGOs/ Gram Panchayats/ Urban Local Bodies should have at least two years of field experience in the recharge technologies that has direct relevance to social upliftment. The work should be original or an addition or innovation or improvement to the existing or traditional practices and prevalent techniques. The works to be considered for the Puraskar/Award, should meet the following criteria.

- Area of operation should be largely dependent on ground water.
- The artificial recharge works implemented to address the issues must bring out both tangible and non-tangible outcomes.
- Recharge structures should have been designed based on sound scientific considerations for their operation at optimal efficiency.
- Successful implementation of the practice and its replicability.
- Community participation and awareness including gender participation.

3. Evaluation Criteria for Selection

A Selection Committee will examine the eligible applications received as per the procedure laid down at para 6, for the practices adopted for addressing the issues pertaining to augmentation of ground water resource particularly in water deficit areas having problems of decline in ground water levels and ground water quality deterioration in given watershed/ area/ Panchayat/ Urban local area and evaluate the same for consideration for suitability of Bhoomijal Samvardhan Puraskar based on a scheme of marks as indicated below.

Sl. No	Criteria	Marks
1	Relevance and significance of the work done during the last two years	10
2	Contribution for sustainability of ground water resources and its acceptance by local community	25
3	Impact assessment of the practice/ innovation implemented for ground water recharge and improvement in ground water quality	25
4	Scope of replicability and suitability of transfer to other areas	15
5	Economic viability of the innovative technique/ practice including environmental advantages	25
Total Marks		**100**

To qualify for the Puraskar, a minimum score of 50 marks is required. The recommended applications received from various Nodal Departments of the State Governments / UTs will be scrutinised by the Members of the Selection Committee. The Committee will short list nine applications from each zone i.e. 3 applications each for the NGOs, Gram Panchayats and Urban Local Bodies respectively. These applications will be considered by the selection comm ittee for finalisation of one Puraskar each for NGO, Gram Panchayat and Urban Local Body respectively and thus there would be three Puraskars for each zone. In all there will be 18 Puraskars for all the six zones taken together. There will be one National Water Award for the best innovative practice of ground water augmentation through rain water harvesting and artificial recharge from amongst 18 award winners of the Bhoomijal samvardhan Puraskar. The decision of the Chairman of the committee shall be final in the matter.

4. Selection Committee for Evaluation

There shall be a Selection Committee notified by the Ministry of Water Resources for evaluation headed by a Chairperson and four Expert Members. The Commissioner (GW), Ministry of Water Resources shall act as Secretary of the Committee.

5. Composition & Citation of the Bhoomijal Samvardhan Puraskar and National Water Award

The Puraskar shall consist of a cash award of Rs.1 Lakh each and a plaque with citation. There will be 18 Puraskars in total. One each shall be given for the three different categories i.e. *NGO, Gram Panchayat and Urban Local Body* in each zone. Thus there would be three Puraskars for each zone. For the purpose of Puraskars the whole country shall be divided in six zones namely; Northern, Eastern, Southern, Western, Central and North Eastern. The Sates/UTs included in different zones are as follows:

1. Northern Zone - Jammu & Kashmir, Himachal Pradesh, Punjab, Haryana, Delhi, Uttar Pradesh, Uttaranchal and Chandigarh.
2. Eastern Zone - Bihar, West Bengal, Orissa, Jharkhand and Andaman & Nicobar Islands.
3. Southern Zone - Andhra Pradesh, Tamil Nadu, Kerala, Karnataka, Goa, Pondicherry and Lakshdweep Islands
4. Western Zone - Rajasthan, Gujarat, Maharashtra, Daman & Diu and Dadra & Nagar Haveli.
5. Central Zone - Madhya Pradesh and Chhattisgarh.
6. North Eastern Zone- Arunachal Pradesh, Assam, Meghalaya, Manipur, Mizoram, Nagaland, Tripura and Sikkim.

In addition, there will be one National Water Award consisting of a cash award of Rs. 10 lakhs and a plaque with citation. The National Water Award shall be given for the best innovative practice of ground water augmentation through rain water harvesting and artificial recharge from amongst 18 award winners of the Bhoomijal Samvardhan Puraskar

6. Procedure for forwarding the Application for Puraskar/Award

Following procedure is to be followed for forwarding eligible applications for the Puraskar/Award

1. Eligible NGOs/Gram Panchayats / *Urban Local Bodies* shall submit their applications to the concerned District Magistrate / Collector through Block Development Officer (B.D.O.) concerned / the Chief Executive Officer concerned of the Zilla Panchayat/ the concerned authority of the Urban Local Body.

2. The District Magistrate / Collector after their recommendations shall forward the applications to the concerned nodal department viz. Water Resources, Ground Water, Irrigation Department, etc. of the State Government / UT.

3. The technical scrutiny of such applications shall be done by a State Level Committee comprising three Members drawn from the concerned Nodal Department, Agriculture Department of the State Govt. / UT and the concerned Regional Director of CGWB. The Committee, after technical scrutiny, shall short list three best applications in each category i.e. NGO / Gram Panchayat / *Urban Local Body*.

4. The Nodal department of the State Govt./ UT concerned will forward the short listed applications with the recommendations of the State Level Committee to the Secretary of the Selection Committee.

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APPLICATION FORM FOR BHOOMIJAL SAMVARDHAN PURASKAR & NATIONAL WATER AWARD

(For Non Governmental Organizations / Gram Panchayats / Urban Local Bodies for innovative practices for ground water augmentation through Rainwater Harvesting and Artificial Recharge to Ground Water)

1. Name of the NGO/ Gram Panchayat / Urban Local Body*
(* Urban Local Body for population up to 1 lakh)
………………………………………………….

2. Brief Profile ………………………………………………….
(NGO/ Gram Panchayat/ Urban Local Body)

a. Complete Postal Address
……………………………………………………………………

i) Phone No. :

ii) Fax No. :

iii) E-mail :

3. Previous Achievements (in water sector)……………………………………..

4. Brief description about the work done (in 1000 words), indicating

(i) Area of implementation
(ii) Pre- and Post- scenario
(iii) Works implemented
(iv) Total benefits accrued (tangible & non-tangible)
(v) Type of innovative methodology/technology adopted
(vi) Outputs and outcomes
(vii) Benefit – cost ratio
(viii) Sustainability
(ix) Scope of replication
(x) Awareness generated

5. Name of the proposer ………………………………………………………

Position
…………………………………………………………………….

Address………………………………………………………………

Signature……………………………………………………………

6. Name of the Seconder ……………………………………………………

Position

……………………………………………………………………….

Address

………………………………………………………………………

Signature……………………………………………………………

7. Confirmation by the proposer that the NGO/ Gram Panchayat/ Urban Local Body has agreed for this Puraskar.

8. A statement by the Proposer/ Seconder not exceeding 1000 words explaining why the nominee should be considered for this Puraskar. This should highlight aspects like (i) Relevance and significance of the work for the last two years from the regional and/or national perspective (ii) Contribution for development of sustainability of ground water resources and its acceptance by local community (iii) Impact assessment of the practice/ innovation implemented for ground water recharge and improvement in ground water quality (iv) Scope of replicability and suitability of transfer to other communities (v) Economic viability of the innovative technique/ practice including environmental advantages

9. Whether the achievements have already been recognized for Puraskar by any other institution/ organization. If so, name of the institution/ organization, Puraskar and year.

10. Recommendation by the concerned District Magistrate / Collector through Block Development Officer (B.D.O.) / the Chief Executive Officer of the Zilla Panchayat/ the concerned authority of the Urban Local Body.

11. Recommendation of the concerned State Govt. Dept.

Note: The last date for receipt of nominations for the Puraskar to be submitted by the concerned Nodal Department of the State Government to the Secretary of the Selection Committee for the current year is 30th July, 2007 and for Puraskar to be given in future, the last date of nomination will be December, 31st of the preceding year.