WATER MANAGEMENT TOWARDS NATIONAL FOOD SECURITY

GESTION DE L'EAU VERS LA SECURITE ALIMENTAIRE NATIONALE

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ABSTRACT

Presently, the population of India is 1210 million and going to be stabilized between 1500 and 1600 million by 2050. While there is sufficient a buffer stock of food grains, the low purchasing power of a large population, to the extent of about 260 million, denies them accessibility to the desirable levels of nutrition. This signifies the momentum required for the production of additional food grains in the years to come for ensuring the food security for the growing population. The states of Haryana, Punjab and Uttar Pradesh contribute nearly 95 % of wheat and 51 % of rice to the central food grains pool. About 70% of irrigation in these states is supplemented by ground water, which is fast depleting. Keeping in view the above points, the present study "Water Management for Food Security in Haryana, Punjab and Western U.P." has been carried out to achieve it by adopting best water management practices.

Key words: *Water management, Food security, groundwater irrigation, Population, growth, Field study, India.*

RESUME

A présent, la population de l'Inde est de l'ordre de 1210 millions qui sera stabilisée entre 1500 et 1600 millions d'ici à l'an 2050. Alors qu'il y a un stock de sécurité de grains alimentaires, la réduction du pouvoir d'achat d'une grande partie de population (environ 260 millions d'ahbitants) a donné lieu à l'inaccessibilité de nutrition au niveau désirable. Cela signifie l'exigence de la production supplémentaire de grains dans les années à venir pour assurer la sécurité alimentaire de la population croissante.

Les Etats de Haryana, de Penjab et d'Uttar Pradesh contribuent presque à 95% du blé et

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de 51% du riz au stock central de grains. Environ 70% des besoins en eau d'irrigation de ces Etats sont satisfaits par l'eau souterraine, qui réduit vite. Compte tenu de cas points, l'étude actuelle est effectuée pour réaliser "la Gestion de l'eau pour la Sécurité alimentaire dans les Etats de Haryana, de Penjab et d'U.P Occidental" en adoptant les meilleures pratiques de gestion d'eau.

Mots clés: *Gestion de l'eau, sécurité alimentaire, irrigation par l'eau souterraine, population, croissance, enquête sur le terrain, Inde.*

1. INTRODUCTION

Food security has been the main focus of India's economy and therefore expansion of irrigation facilities received top priority in India's planning over the years. Ultimate irrigation potential in the country comprising major, medium minor irrigation including groundwater sub sectors is estimated at 139.95 million hectares (M ha), out of which potential created is 99.736 M ha having a balance of 40.214 M ha for future development. Vast network of canal system has been created to apply the surface water for irrigation purposes. In India about 40% of the cultivated cropped area is irrigated through large canal water distribution system and 60% by groundwater resources. Due to significant development in irrigation sector and ensured availability of agricultural inputs, there has been spectacular increase in food grain production from 50.82 M tones in 1950-51 to 235.88 M tones in 2010-11. During the same period, the country's population increased from 361 million to 1210 millions in 2011. The relatively more recent and the future projected trends in food grain production and population growth are given in Table 1.

Table 1. Food grains production and population in India (2001-02 – 2050-51)

Year	Total Food grains (M tones)	Population (millions)
2001-02	212.85	1028.83
2002-03	174.77	1062.38
2003-04	213.19	1079.11
2004-05	198.36	1075.11
2005-06	208.60	1112.18
2006-07	217.28	1128.52
2007-08	230.78	1144.73
2008-09	234.47	1162.85
2009-10	218.11	1184.97
2010-11	235.88	1210.00
2021-22	325.0*	1380.21*
2050-51	382.0*	1600.00*

*projected

Annual utilizable ground water reserve estimated as 433 km^3 is 38.5% of the total 1123 km^3 annually available water resources in the country. Ground water meets nearly 60% irrigation, 85% of rural and 50% of urban and industrial needs of the country. It is estimated that the total annual groundwater withdrawal is about 213 billion cubic meters (BCM). The ultimate irrigation potential from groundwater resource is 64.05 M ha as compared to 46.0 M ha currently under groundwater irrigation. However, in most of the states particularly Haryana, Punjab and Western U P groundwater irrigation potential created has far exceeded the ultimate potential indicating over exploitation of ground water leading to increase in cost of pumping and reduction in groundwater quantity and quality (Table 2).

Hence, in spite of the tremendous progress in irrigation sector both surface and ground water, the increase in agricultural production has not been sustainable and proportional since in both sectors water management problems have arisen, which slow down the enhancement in crop productivity. Low irrigation efficiency in canal commands is also a cause of concern.

Table 2. Groundwater irrigation potential utilized in Rajasthan, Haryana, Punjab and Western U P

States Unit	Ultimate groundwater irrigation potential (000 ha)	Groundwater Irrigation potential utilized (000 ha)	% of ultimate groundwater irrigation potential	Remarks
Rajasthan	1778	3844	216	Overexploitation
Haryana	1462	2267	155	Overexploitation
Punjab	2917	5748	197	Overexploitation
Western U.P.	16295	14010	86	Under exploitation

Keeping these points in view, study was undertaken to assess the problems of waterlogging /salinity in canal commands and depleting water table in ground water irrigated areas of Haryana, Punjab and Western U.P. the three of the Food Bowls of India.

2. EXPERIMENTAL

A field study in selected districts and blocks of Haryana, Punjab and Western UP was done during 2010-11 to ascertain the nature and extent of water management problems in areas utilizing surface as well as groundwater for irrigation. For analyzing the constraints to productivity by utilizing surface and ground water, data on irrigation system, cropping sequence, groundwater level and rainfall pattern were considered. Discussion was held with farmers and field staff to get the factual position of the performance indicators. Data on crops and cropping sequence were collected from the official records and farmers. Groundwater table at sample location was recorded in dug well and tube wells wherever possible. Table 3 gives details on the surveyed blocks in the study area in each state.

3. APPRAISAL OF IRRIGATION SYSTEMS

Water productivity in major, medium and minor irrigation systems is still very low as compared to irrigated areas of other countries. Quality of soil and water is getting deteriorated and crop production suffers seriously. Irrigation efficiencies are low ranging between 35-40% in major and medium and 60-65% in minor irrigation projects, respectively. Moreover, water demands for irrigation and other sectors particularly domestic and industrial are escalating. It is essential to assess the performance of irrigation systems thoroughly as it utilizes maximum water, and adopt corrective measures urgently to improve the productivity of the system. The source-wise irrigation scenario in these states is given in Table-4.

Table 3. Details of blocks surveyed

States	Total Blocks	Over Exploited Blocks	Sample Blocks (5%)	Name of Sample Blocks
Haryana	113	55	6	Barara (Ambala), Narnaul (Mahendergarh), Samalkha (Panipat), Shahbad (Kurukshetra), Khol (Rewari), Karnal (Karnal)
Punjab	137	103	7	Moga (Moga), Sangrur (Sangrur),Verka (Amritsar),Sirhind (Fatehgarh), Patiala (Patiala), Muktsar (Muktsar), Adampur (Jalandhar)
Western UP	269	45	13	Bichpu Bichpuri (Agra), Atrauli (Aligarh), Loni (Ghaziabad), Baghpat (Baghpat), Gulaothi (Bulandsahar), Tundla (Firozabad) Sasni (Hathras), Gajraula (JP Nagar), Chhata (Mathura) Kandhla (Muzaffarnagar), Sambhal (Moradabad), Chamraua (Rampur), Deoband (Saharanpur)

Table 4. Water source-wise irrigated area in the three states

S No.	Description / Source	Haryana	Punjab	Western UP
1.	Geographical Area	4421.0	5036 .0	7983.0
2.	Cultivable Area	3809.0	4201.0	6057.0
3.	Canal Irrigation	1585.4	1189 .0	756.0
4.	Tube well Irrigation	1350.6	2888.0	4172.0
5.	Other Sources	14.0	0.0	642.0
6.	Total Irrigated area	2950.0	4077.0	5570.0

It is evident that Haryana, Punjab and Western U P have about 77.5%, 97% and 92% cropped area under irrigation. However, due to exponential growth of tube wells in these states, groundwater is depleting at alarming rate resulting into over exploitation.

Table-5 Groundwater availability and exploitation status

Dynamic Resources	Haryana	Punjab	Uttar Pradesh
Annual replenishable ground water resource	9.31 x 103 MCM	23.78x 103 MCM	76.35x103 MCM
Net annual groundwater availability	8.63 x 103 MCM	21.44x103 CM	70.18 x 103 MCM
Annual groundwater draft	9.45 x 103 MCM	31.16x103MCM	48.78 x 103 MCM
Stage of groundwater development	109 %	145 %	70 %
Developmental Status			
Over-exploited blocks	55	103	37
Critical blocks	11	5	13
Semi- critical blocks	5	4	88

In Haryana, rate of groundwater depletion ranged from 10.4 cm/ year in district Ambala to 73.4 cm/year in Mahendergarh district. Depth to water table varied from less than 2 m (western-central part) to over 40 m below ground surface. Deep water table conditions i.e. 20m to 40m exist in south-western parts of the state.

In Punjab, groundwater level has been depleting in the range of 4 m to 16 m during last three decades. The rate of decrease in water table varied from 74 cm/year in Amritsar district to 104 cm/year in Patiala district. In major part of the state, depth to water table ranges between 15m to 30m below ground level (bgl). However, shallow water levels within 5 m occur in south western part of the state. In Western Uttar Pradesh, rate of groundwater depletion varied from 20 cm/year in Rampur district to 140cm/year in Bagpat district. Average rate of depletion varied from 4 cm to 100 cm/year in different districts of Western U.P. Groundwater table between 10m-20m exists in Agra, Aligarh, Hathras and Moradabad districts while utilizable water table depths (2-5m) are in Rampur, Saharanpur and Mathura districts.

Cause of depletion of Ground Water

The main factor responsible for groundwater depletion is intensive agriculture with main cropping sequence of rice-wheat, which is more remunerative and socially acceptable from consumption/domestic needs point of view. In Haryana state the area under rice crop has increased by 460% and that of wheat by 232% during last forty years (1966-67 to 2007-08) which clearly indicates shift towards rice-wheat rotation. This shifting trend has reduced area under pulses to one-fifth and that under sorghum to two-third. Because of higher water requirement for rice and wheat, the irrigation intensity increased to 200% and number of shallow tube wells increased by 20-35 times numbering to 0.7 Million during last 3-4 decades. In Punjab, rice occupied less than 5% of the total cropped area during early sixties, now covers nearly 32% (1/3) of the total cropped area. Similarly area under wheat crop during the same period increased from 27% to nearly 43% of the total cropped area. Season wise data indicate that in *kharif* (monsoon cultivation season: June - October) rice covers about 73% area and wheat in *rabi* (winter cultivation season: Novenber – April) accounts for 92%

area in the state. Because of this trend, area under maize, millets, pulses and barley reduced sharply. In some parts of Punjab farmers are growing summer rice crop starting in May. This requires 35-40% more irrigation water as compared to normal rice crop transplanted in the 3rd week of June.

Table- 7 Effect of date of transplanting on rice evapotranspiration (mm)

Year	Date of Transplanting/ Evaporation			
	May 20	May 31	June 10	June 20
1990-91	835 mm	759	669	613
1991-92	833	767	745	725
1992-93	822	720	633	537
1993-94	891	783	707	694
1994-95	935	781	664	584
1995-96	712	639	565	487
1996-97	754	705	652	627
1997-98	696	675	651	612
1998-99	699	650	611	583
Avg	797	720	655	607

The situation in western U P is no different than that of Haryana and Punjab. Area of rice has increased by 20-30% during last five years particularly in critical category districts (90-100% exploitation of groundwater). Then, some districts in Western UP are growing vegetables, sunflower, mentha and pearl millet during May-June requiring more water and hence exerting additional stress on groundwater. It is interesting that farmers are extracting groundwater excessively and indiscriminately by using their own pumping sets. Area irrigated by Govt. tube wells is shrinking and that by canals is almost constant. Irrigation intensity has therefore enhanced in these critical areas (Table- 8) due to excessive ground water withdrawal. However, horizontal expansion of irrigated area is almost constant.

In nutshell, the groundwater is being extracted excessively and hence water level has gone down very deep beyond the capacity of centrifugal pumps and farmers are using costly submersible pumps to extract groundwater from deeper depths having no knowledge of its future repercussions. Situation of groundwater exploitation is becoming serious day by day and if the trend continues, ‘Food Bowl of India’ may become ‘Food Deficit region of India’ in a few years.

For sustainable use of groundwater reserve its recharge either through rainfall or excess irrigation return flow is essential. Unfortunately rainfall pattern during the last 5 years has been quite sub-normal (Table 9)

Table -8 - Irrigated area (ha) by Different Sources of irrigation during last five years in Western U.P.

District	Canals		Govt.T.W.		Private T.W.		Ponds/Wells		Area Irrigated	
	2005-06	2009-10	2005-06	2009-10	2005-06	2009-10	2005-06	2009-10	2005-06	2009-10
Agra	27910	30151	4176	7247	213346	216028	3246	450	248678	253876
Aligarh	33324	34628	5053	6625	249678	248440	59	350	288114	290043
Bulandsahar	25102	31280	4983	2921	220816	219015	12687	6047	263588	259263
Firozabad	17512	18462	957	307	153627	155242	2240	1540	174336	175551
Ghaziabad	22250	20232	29000	21000	102898	107019	4500	3921	158648	152172
Hathras	14416	12608	1354	591	131441	133303	-	-	147211	146502
J.P.Nagar	-	58	325	277	48879	55837	64493	59761	113697	115933
Mathura	108104	106408	-	-	151940	161350	130	-	260174	267758
Moradabad	12170	10718	5595	4455	154141	119882	68265	21158	240171	256213
Muzaffarnagar	76823	75211	7555	5529	237532	242676	407	48	322317	323464
Rampur	1857	1313	1920	172	125476	117199	452	314	129705	118998
Saharanpur	42665	41089	9245	9179	203499	207522	-	-	255409	257790

Table 9. Rainfall (mm) during last five years in Punjab

District	Normal Rainfall (mm)	Rainfall (mm)					Avg. Rainfall in 5 years
		2005	2006	2007	2008	2009	
Amritsar	593	693.4	957.5	575.0	869.3	276.4	674.3
Jhalandhar	701	833.9	576.9	622.8	724.7	615.4	674.7
Moga	498	326.7	314.3	283.8	417.8	328.8	334.3
Muktsar	425	262.6	344.4	439.7	382.6	176.9	321.2
Patiala	754	770.9	436.8	473.7	1320.0	517.0	703.7
Sangrur	599	281.8	332.6	216.5	418.5	324.5	314.8
Fatehgarh Sahib	692	362.0	322.8	156.0	206.1	161.7	241.7

In most of the cases, it has been 25-50% of its normal rainfall which is inadequate to recharge the depleting groundwater aquifers in the area.

Canal Irrigated Areas

India has second largest canal network in the world with ultimate irrigation potential of 139.8 M ha. Inefficient management of canal regulatory system has over irrigated the head reaches and tail reaches remained unirrigated. Problem of water logging in canal irrigated & nearby areas has affected crop production adversely. Apart from water logging, these areas are also experiencing salinity/alkali problems rendering crops vulnerable. Haryana and Punjab states having 54.6% and 29% irrigated area under canal command have sizeable portion of agricultural land becoming unproductive due to salinity and waterlogging (Table 10).

Table 10. Waterlogged and poor groundwater quality area in Haryana and Punjab

State	Total area (ha)	Water-logged Area (ha)	Percent of total area	Poor ground water quality area (ha)	Percent of total area
Haryana	4421200	530544	12	423011	9.5
Punjab	5036000	956840	19	795700	15.8
Western U.P.	-	Nil	Nil	Nil	Nil

Integrated Water Resources Management (IWRM)

Amelioration technology: On one hand inadequate water for irrigation and on the other hand excess water/salinity, which is impairing the crop growth and yield. Suggested technology for irrigated areas is summarized below. The concept of IWRM is based on:

- Recognizing water as a finite resource.
- Recognizing importance of water management.
- Treating water and soil/ land as economic good.
- Adapting participatory approach in water management.

(A) Minimizing irrigation requirement of crops

(i) **Laser Leveling of Fields (LL).** Uneven plant growth is usually observed in undulating and uneven spots on farm lands. Leveling of fields is essential for uniform distribution of irrigation water and applied fertilizers. Laser leveler is quite effective for precision leveling (+20mm) of fields ensuring saving of irrigation water by 10 to 30% in paddy fields & other crops and hence higher water productivity and crop yields (Table 11).

Table 11. Effect of laser leveling (LL) on water productivity of paddy in comparison to conventionally leveled (CL) Fields

Site No	Irrigation Depth(cm)			Water Productivity (kg/ha-cm)		
	LL	CL	Water Saving (%)	LL	CL	Increase (%)
1	78.5	85.2	7.9	63.7	54.0	18.0
2	64.0	76.0	15.8	71.1	56.6	25.6
3	67.5	96.0	29.7	74.1	46.9	58.0
4	63.0	86.0	26.7	66.7	43.0	55.1
5	62.7	70.0	10.4	69.4	60.0	15.7
6	72.0	91.0	20.9	62.5	46.0	35.3
7*	68	83.6	18.7	67.9	51.1	36.4

* Source: CSSRI, Karnal

Saving of water by using Laser leveling of fields is reported from 7.9% to 29.7% whereas water productivity has been increased from 15.7% to 55.1%. This method is easy to adopt by the farmer which will lead to food security.

(ii) **Drip and Sprinkler Irrigation Methods.** In surface method of irrigation more than 50% of the applied water is wasted either through seepage or deep percolation. Uncontrolled application also results in ponding of excess water causing leaching of plant nutrients and oxygen stress to roots.

In drip system water is applied in drops or at a very low rate through emitters near plant roots and all sorts of wastages are avoided attaining 90-95% irrigation efficiency. Fertilizers nutrients and chemicals (pesticides/herbicides) are also mixed in water tank and applied with water resulting in efficient uptake/utilization of nutrients and effective control of weeds and insects. Thus there is saving of irrigation water and increase in quality and quantity of the produce. This system is more suitable to vegetables and orchards crops. This is also suitable for using brackish/saline groundwater for irrigation.

Utility of drip system of irrigation in terms of increase in yield and saving of irrigation water in comparison to surface method of irrigation for field crops is shown in Table 12.

Table -12 Benefits of drip irrigation over surface irrigation in field crops

Crops	Yield (t/ha)			Water Use (m3/ha)		
	Surface	Drip	Increase in yield (%)	Surface	Drip	Reduction in water demand (%)
Sugarcane	75.0	175.0	133.3	2700	1240	54.1
Cotton	2.3	4.2	82.6	900	420	53.3
Potato	12.7	27.2	114.2	600	275	54.2
Gram	3.1	5.5	77.4	452	262	42.0
Chilly	2.3	3.8	65.2	427	245	42.6
Onion	36.6	56.2	53.5	520	280	46.2
Groundnut	4.2	6.1	45.2	655	420	35.9

Source; - Water Resources Agency, U.P.

(iii) **Crop Diversification.** Large scale adoption of rice-wheat cropping system is the main factor for over exploitation of ground water in all the three states. Alternate crops and cropping systems having low water requirements are better options for reducing ground water extraction. Alternative crops suggested are:

Kharif- maize, cotton, sorghum, pulses, groundnut and ***Rabi-***mustard (raya), gram, pulse

By adopting the alternative cropping sequence farmers can save 20-30% irrigation water and reduce the stress on ground water extraction. It is found that replacing 0.5 M ha from paddy –wheat rotation will save about 77,500 ha-m of irrigation water.

(iv) **System of Rice Intensification (SRI).** System of Rice Intensification (SRI) is a new innovative approach emphasizing relatively younger seedlings (15 days old), wider spacing (25x30cm) and not adhering to continuous submergence. On an average 41.8% of irrigation water and 26.9% of its water requirement may be reduced by adopting the SRI practice. Crop water requirement and saving of irrigation water under SRI is shown in Table 13.

(v) **Use of Effluents and Sewage for Irrigation.** Agriculture sector in India has been and will remain the major user of water for irrigation. However, with increasing demands of domestic and industrial sectors, the share of water allocated to irrigation sector is likely to decrease by 10-15 % in next two decades. It is necessary to explore the possibility of using other sources of water such as sewage and industrial effluents for irrigation after their proper diagnosis and treatment. Waste water like sewage and other carbon rich effluents of paper, sugar and dairy industries may be first treated to lower the BOD (bio-chemical oxygen demand) to safer limit (50mgL^{-1}) and then may be used for irrigation with desired dilutions to have tolerable limits of dissolved solids. Paper Mills reated effluent in Shamli (Muzaffarnagar,U.P.) has been successfully used on farmers' fields for irrigation (Table 14) in 1:1 fresh water and effluent ratio.

Table - 13 Water saving under SRI (System of Rice Intensification) cultivation

Treatment	Irrigation Requirement (mm)		CropWater Requirement (mm)		Saving of Irrigation water (%)			Saving of total water (%)		
	2003	2004	2003	2004	2003	2004	Avg	2003	2004	Avg
Irrigation Regime										
One day drainage	760	800	1315.67	1312.33	29.62	28.57	29.1	9.38	12.14	19.26
Two day drainage	440	560	1025.67	1112.67	59.25	50	54.63	37.14	31.19	34.53
Plant Density										
20x20 cm	600	680	1170.67	1217	44.44	39.29	41.87	28.25	25.52	26.89
30x30 cm	600	680	1170.67	1217	44.44	39.29	41.87	8.25	25.52	26.89
40x40 cm	600	680	1170.67	1217	44.44	39.29	41.87	28.25	25.52	26.89
Age of Seedlings										
15 day old	600	680	1160.8	1207	44.44	39.29	41.87	28.25	26.13	27.53
20 day old	600	680	1170	1217	44.44	39.29	41.87	28.25	25.52	26.92
25 day old	600	680	1182	1217	44.44	39.29	41.87	27.57	24.9	26.24
Control										
CS + 20x15 cm + 25 day old seedling	1080	1120	1632	1634	100	100	100	100	100	100

Source:-IARI, New Delhi. CS: Continuous submergence.

Table 14. Effect of paper mills effluent on paddy yield and soil properties

S.N.	Irrigation	Paddy Yield (q /h)	Infiltration Rate in Irrigated Soil (cm/h)	Organic Carbon (%)
1	Tubewell water (100%)	42.2	0.90	0.45
2	Treated Effluent + Tube well water (50%+50%)	44.6	1.22	0.54
3	Treated Effluent (100%)	42.5	1.74	0.68

Source- IARI, New Delhi

(vi) **Farmers' groups (Societies) for effective management of irrigation.** National Water Policy (2002) has advocated for involving farmers in various aspects of management of irrigation systems, particularly in water distribution and collection of water charges. Involvement of the farmers' group should be at the following stages.

- Planning and design of the irrigation system.
- Construction, operation and maintenance of system.
- Equitable water distribution
- Financial aspects

B. Augmenting Groundwater Reserve by Rainwater Harvesting

Rainwater harvesting is the practice of collecting rainfall runoff at suitable places and using it to meet irrigation, recharge and other needs. Overexploitation of groundwater in rural areas and reduced infiltration of rainwater into soil profile due to increased urbanization necessitates the harvesting of rainfall and artificially recharging the groundwater.
Rooftop rainwater harvesting is very important in urban areas to enhance depleting ground water reserve and/or using it for kitchen gardening.

Artificial recharge is basically accomplished by two basic methods. First diverting the rainfall through rooftop water harvesting or sloppy terrain into small ponds, trenches/shallow basins and allowed to percolate and recharge the groundwater.

Groundwater recharge is also based on well injection techniques and involve passing of excess rain and canal water to suitable aquifer zones after filtration under gravity.

a. **Recharge Shaft.** It consists of a bore hole of 45 cm dia filled with gravel to carry filtered water to subsurface sandy zones. The surface/subsurface runoff is first passed through a recharge filter consisting of layers of coarse sand, small gravel and boulders in a small masonry chamber to safeguard against clogging. A high pressure PVC pipe of 12.5 cm dia and slotted in sandy zones, is provided for cleaning of clogged sediments in the shaft with compressed air, if needed. The depth of recharge shafts is decided based on the criterion to provide minimum 10m cumulative sand layers for recharge (Figure 1)

b. **Recharge Cavity.** A recharge cavity is similar to a cavity tube well coupled with a graded filter of the type used in recharge shaft. It is constructed by drilling a bore hole until a sandy layer is found below a clay layer, a blind PVC casing pipe is drilled through the clay layer and sand is pumped out until a stable cavity is developed below it. A recharge cavity can be used for occasional pumping also.

c. **Recharge Wells.** Recharge wells are similar to recharge shaft except that boreholes of different sizes (17.5 - 40 cm diameter) and filter chamber of different shapes have been made at different sites. Placement of 12.5 cm dia PVC pipes and 8-20 mm size pebbles in the bore holes was facilitated through air compressor.

d. **Pond Conservation.** Renovation of existing farm ponds (desilting, deepening and shaping) help in rainwater conservation to provide supplemental irrigation to crops.Village ponds have been helpful in maintaining groundwater level at sustainable depth. However, rapid population increase has forced people to build dwelling units after these water bodies silted up. Block and village committees must renovate the silted and abondoned ponds or dug on wasteland to safeguard the groundwater reserve.

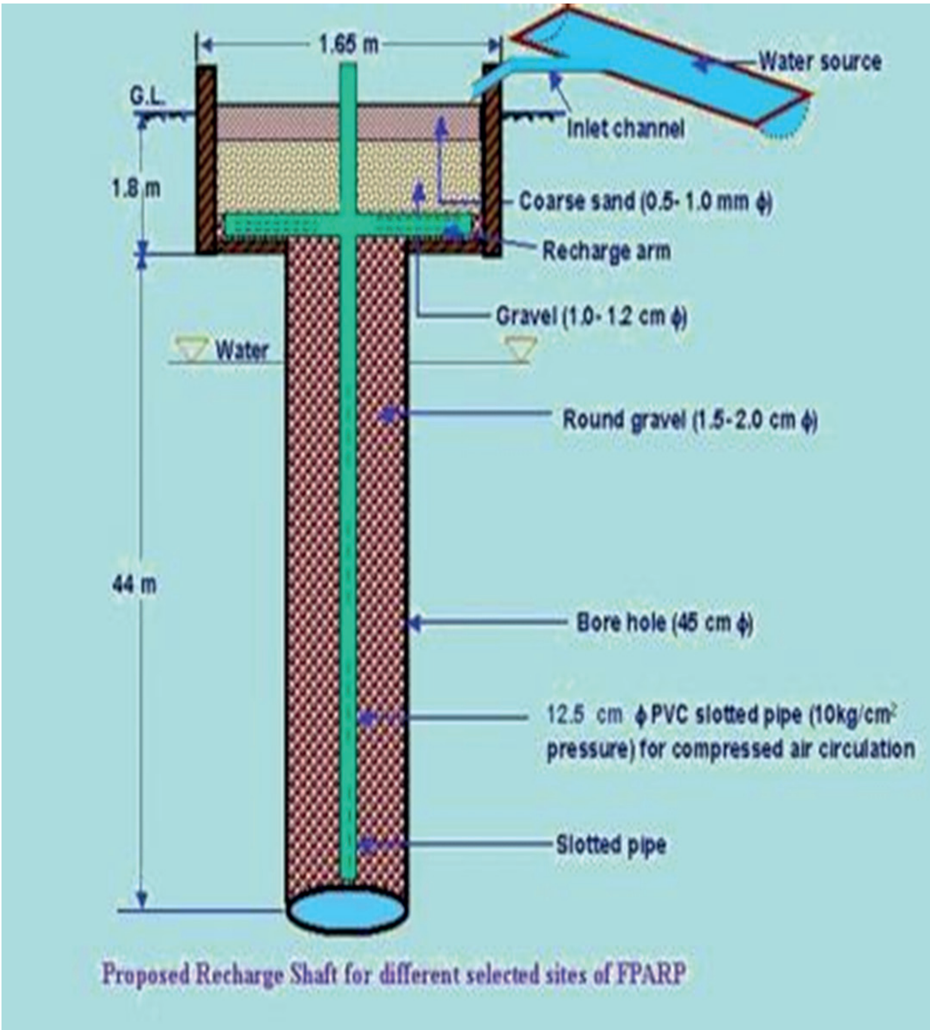

Fig-1 Recharge Shaft

C. Addressing Waterlogging and Salinity Problems

i **Installation of drainage system.** Provision of drainage is of prime significance to reclaim the saline and shallow water table lands. Trails were conducted by CSSRI, Karnal at Rohtak and PAU, Ludhiana in affected areas to reclaim these areas by installing sub-surface tile drainage system. At Rohtak (Sampla farm) Drain laterals made of cement concrete pipes (1:1.5:2) having 10 cm internal dia and 30cm length were placed at 1.75 meter depth from the surface. Drain spacing ranged from 25m to 75m. A gravel layer (7.5cm) was placed above the drain lines. Efficiency of the drainage system after rainy season of 1984 in terms of salt removal through drained water is given in Table 15.

Table 15. Decrease in Soil Salinity due to Sub-Surface Drainage at Sampla (Rohtak), Haryana

Soil Depth (cm)	Drain Spacing (m)								
	25			50			75		
	ECe (dSm^{-1})								
	June-84	Oct-84	Salt Drained (t/ha)	June-84	Oct-84	Salt Drained (t/ha)	June-84	Oct-84	Salt Drained (t/ha)
0-20	50.7	5.3	9.5	50.7	8.1	9.4	46.1	8.3	6.2
20-40	23.6	4.0	4.2	19.4	4.7	3.8	26.4	9.1	3.2
40-60	19.4	3.7	3.9	15.8	7.9	2.2	13.4	8.9	0.7
60-90	17.0	4.8	5.6	16.8	11.1	1.8	11.1	9.4	0.4
90-120	12.2	7.6	2.4	15.5	14.3	0.5	12.6	10.2	0.8
Total			25.5			17.7			11.3

Rain water (effective rainfall 275 mm) leached the salts to the tune of 25.5, 17.7 and 11.3 t/ha under 25, 50 and 75 meter spacing, respectively. In wide drains spacing efficiency of salt drainage was minimum. However, salt balance was always negative and after 3-4 years, crop yields of both *kharif* and *rabi* were stabilized and soil salinity and water table depths became within the tolerable limits of the crops. Drain water was collected in a big sump and discharged out during rains in nearby drains. Effort are being made to utilize the drained saline water for tree plantation and psciculture. In alkali/sodic situations having higher clay content (loam to clay loam) surface drains may also be effective.

ii **Growing of salt and alkali tolerant crops.** Problem of ground water salinity/alkalinity in arid and semiarid parts of the country particularly in the states of Punjab, Haryana and western U.P. is showing increasing trend due to excessive draft of fresh water and its uncontrolled/ unscientific use in canal commands. While reclaiming the saline/sodic and high water table areas through surface or subsurface drainage, selection of salt/alkali tolerant crops and their varieties must be given preference. List of field crops and their varieties both for saline and alkali conditions is given Table 16.

In waterlogged and salt affected areas of Punjab and Haryana states tree plantation is also recommended. It serves a good source of fuel and fodder along with amelioration of soil salinity/alkalinity and shallow water table conditions. Important tree species and their tolerable soil and water salinity (ECw) limits are given in (Table 17).

Table-16 Varieties of fields crops for saline/alkali conditions

S.N.	Crop	Saline Environment	Alkali-Environment
1	Wheat	Raj 2325, Raj 3077, Raj 2560, WH 157	KRL 1-4, KRL-19, Raj 3077, HI 1077
2	Pearl millet	MH 269,331, 427,WHB-60	MH 269, 280, 427, HHB 392
3	Mustard	CS 416, CS 330, Pusa Bold	CS15, CS 52,Varuna, DIRA 336, CS 54
4	Cotton	DHY286, CPD404, G17060, JK276-10-5, GDH-9	Hy6, Sarvottam, LRA 5166
5	Safflower	HUS 205, A-1, Bhima	Manjira, APRR3, A 300
6	Sorghum	SPV-475, 881, 678, 669, CSH 11	SPV 475, 1010, CSH 1, 11, 14
7	Barley	Ratna, RL345, RD103, 137, K169	DL 4, 106, 120, DHS 12

Source-CSSRI,Karnal

Table- 17 Tree species for saline – waterlogged areas

Tree Species	Range of Soil Salinity (ECe dSm^{-1})	Range of Water Salinity (ECw dSm^{-1})
Acacia nilotica	10.6-25.3	27-33
Acacia tortilis	6.8-28.1	12-33
Eucalyptus camaldulensis	10.0-17.9	10-35
Prosopis juliflora	10.3-24.0	32-36
Casuarina equisetifolia	5.6-20.7	10-31
Casuarina glauca 13987	6.5-33.9	12-19
Casuarina obesa 27	9.0-19.5	12-19
Leucaena leucocephala	6.9-23.9	10-25
Tamarix	8.2-21.9	10-32

Source-CSSRI,Karnal

iii. **Biodrainage.** Provision of sub surface drainage in waterlogged saline areas helps in leaching down the salts from the root zone but it is relatively costly option and may have environmental imitations. Biodrainage or removal of excess soil water through plants with high rate of evapotranspiration (ET) on the other hand is environmental friendly and cost effective which can be adopted at least as a preventive measure. Hence, in waterlogged areas planting of cloned Eucalyptus may be very useful in controlling the rising water table situations. Further, plantation may generate revenue, as after five year of plantation farmers could harvest 39 t ha^{-1} wood biomass. Tree species chosen for biodrainage should meet the following requirements:-

1. They should be able to grow fast under prevailing climate and soil conditions.
2. Trees should have high transpiration rate and salt/water use capability
3. Trees should be tolerant to saline conditions
4. Trees should be of good financial value and acceptable social needs
5. Trees should be environmental friendly

Suitable species for biodrainage

1. Eucalyptus camaldulensis, 2. Eucalyptus globules, 3. Eucalyptus tereticornis

4. Acacia Arabica, 5. Acacia militia, 6. Moris alba, 7. Dalbergia sisoo

8. Tamarix articulate, 9. Casurina cunninghamiana

iv **Conjunctive use of saline and fresh water.** Water table rise in areas with shallow and brackish ground water can also be controlled by using saline groundwater directly/ indirectly after mixing with fresh water and installing drainage system preferably underground. Farmers in south-east districts of Punjab, central- west districts of Haryana and south -east districts of U.P. have also access to canal water along with saline/alkaline ground water. Both the water supplies may be used by two ways. The two supplies can be blended such that the salinity (EC) or alkalinity (RSC) of mixed supply is within the safe limit. Formula suggested as:

EC/RSC of blended water = {(Fraction of saline/alkali water) x (EC or RSC of brackish water)}
+ {(Fraction of fresh water) x (EC or RSC of fresh water)}

In the above, EC is in dS/m and RSC is in me/l

Example:- A tube well water having salinity (ECw) of 8.5dSm^{-1} *is blended with fresh water having salinity of 0.2dSm*$^{-1}$ *in the proportion of 50 % each. The salinity (ECw) of blended water will be:* $\{(8.5 \times 0.5) + (0.2 \times 0.5)\} = 4.25 + 0.1 = 4.35$ *dSm*$^{-1}$*.*

Amount of canal and tube well water may also be computed for blending purposes. Mixing may improve the stream size and ensure uniform water distribution in the field. Alternatively two supplies may be used separately at different crop growth stages so that saline water is avoided at sensitive early growth stage of the crop. Hence, cyclic use of poor and good quality water offers both operational and performance (Table 18) advantages over mixing both the supplies. Application of alkali/saline water at later growth stages may not be hazardous. Moreover, physical conditions of the soil remained relatively good for sustaining the yields of rice-wheat system in ground water salinity infested areas. Conjunctive use of fresh and saline/sodic ground water may also reduce the quantity of fresh water to be extracted and thus the rate of water table decline may be slowed down.

Table -18 Effect of alternating canal and alkali water irrigation in rice-wheat system

S.No.	Treatment	Grain yield (t/ ha)	Water Productivity(kg/m^3)		
		Rice	Wheat	Rice	Wheat
1	Canal water	6.9	5.4	0.62	1.80
2	Alkali water	4.3	3.3	0.39	1.20
3	**Cyclic use**				
4	2CW:1AW	6.7	5.3	0.62	1.73
5	1CW:1AW	6.4	5.4	0.58	1.77
6	1CW:2AW	5.8	5.0	0.53	1.60

Conjunctive water use management is a key for maintaining overall sustainability of water resources in the state so as to keep surface water and ground water resources under harmony. Scientifically it is a potential management option for the areas where ground water is either rising or declining and as such conjunctive use management of surface and ground water can suitably resolve the issue of water logging coupled with salinity/alkalinity in canal commands and declining water levels in over exploited areas including urban sprawl.

v **Psciculture in Saline Water.** Water salinity is an important factor for survival, physiology and distribution of many fish species; each having its own range of salinity tolerance and preference. Reproduction stage is relatively less tolerant, up to 7.5 dSm^{-1} ECw. The common carp as well as the Indian major carp species can tolerate the highest water salinity (ECw) of 14.5 dSm^{-1}. The total fish biomass at different salinity level is shown in Figure 2.

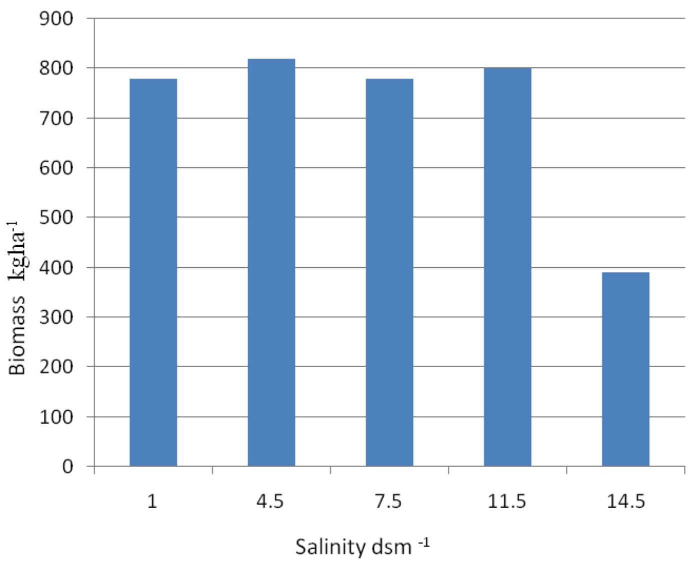

Fig. 2. Fish biomass production at different water salinity

Primary estimates indicated that 1 ha brackish water fish pond can control the water table rise in a 5-25 ha waterlogged irrigated agricultural area and provide a gross income of Rs 80000/ha/annum as compared to about Rs 40000/ha/annum from traditional irrigated agriculture in Haryana state (CSSRI, Karnal).

4. CONCLUSIONS

Based on the scenario of groundwater depletion and water logging /salinity problem in the food bowl region, it is emphasized to adopt efficient irrigation and drainage methodology to reduce irrigation demands of the crops and remove excess water from root zone for other uses. For augmenting groundwater resource measures of rainwater harvesting and storage of excess runoff during monsoon may also be adopted. Further, farmers' active participation is essential for success of all these programmes and overall to achieve the sustainable food security in the country.

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