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Management of Groundwater Resources for Sustainable Agriculture in Haryana

Omvir Singh and Amrita, Kurukshetra, Haryana.

Abstract

Water is the major limiting factor for crop production in semi-arid and arid regions of the world. Due to low and uncertain annual rainfall in these regions the crop water requirement is mainly supplied by supplemental irrigation. Groundwater has emerged as one of the principle source of supplemental irrigation in agricultural development of Haryana, which is located in semi-arid to arid environment. In the absence of adequate surface water quantity, groundwater has become the main sources of irrigation in the state and irrigated area has increased from 1.75 million ha in 1975-76 to 3.1 million ha in 2011-2012. The number of tube wells has also increased from 0.20 million in 1975-76 to 0.73 million in 2011-2012. This has resulted into excessive exploitation of groundwater resources. The indiscriminate withdrawal of groundwater has created a declining water table situation in the state. The average rate of decline over the last 38 years has been about 20 cm per year. In addition, thirteen districts out of twenty one have been categorized as over exploited. The over exploitation of groundwater resources has resulted in extra power consumption, ecological degradation and the sustainability of agricultural production. This paper, therefore, attempts to analyze the problem of declining water table, factors for its depletion and suitable mitigation measures to combat the declining water table problem for sustainable agriculture development in the state. The major mitigation strategies include crop diversification, delay in paddy transplantation, laser leveling, zero tillage technology, bio drainage, and rainwater harvesting for artificial groundwater recharge in the aquifers.

Key words: *Groundwater, Sustainable Agriculture, Irrigation, Green Revolution, Zero Tillage, Haryana*

Introduction

Water is the major limiting factor for crop production in semi-arid and arid regions of the world. Water resources play a vital role in healthy economic growth of a country but their utilization needs to be scientifically planned and managed keeping in view the future demands which are inevitably to increase manifold for domestic, irrigation and industrial purposes. Groundwater resources play a major role in ensuring livelihood security across the world, especially in the economies that depend on agriculture (Shankar et al., 2011). Over the past two decades, groundwater has emerged as one of the principle source of irrigation (Shah et al, 2006). The groundwater revolution has caught hold in the South Asia, the Middle East, and the North America and to a lesser extent in the Africa and South America (Scott and Shah, 2004). South Asia is heavily dependent on groundwater irrigation for supporting its largely agrarian economics. It is the world's largest user of groundwater, accounting for almost 210 km^3 of withdrawals every year (Mukherji and Shah, 2005). For India, it is estimated that in the years 2010, 2025 and 2050, of total water use in the irrigation sector will continue to dominate with 78%, 74% and 72% respectively (Vyas, 2001).

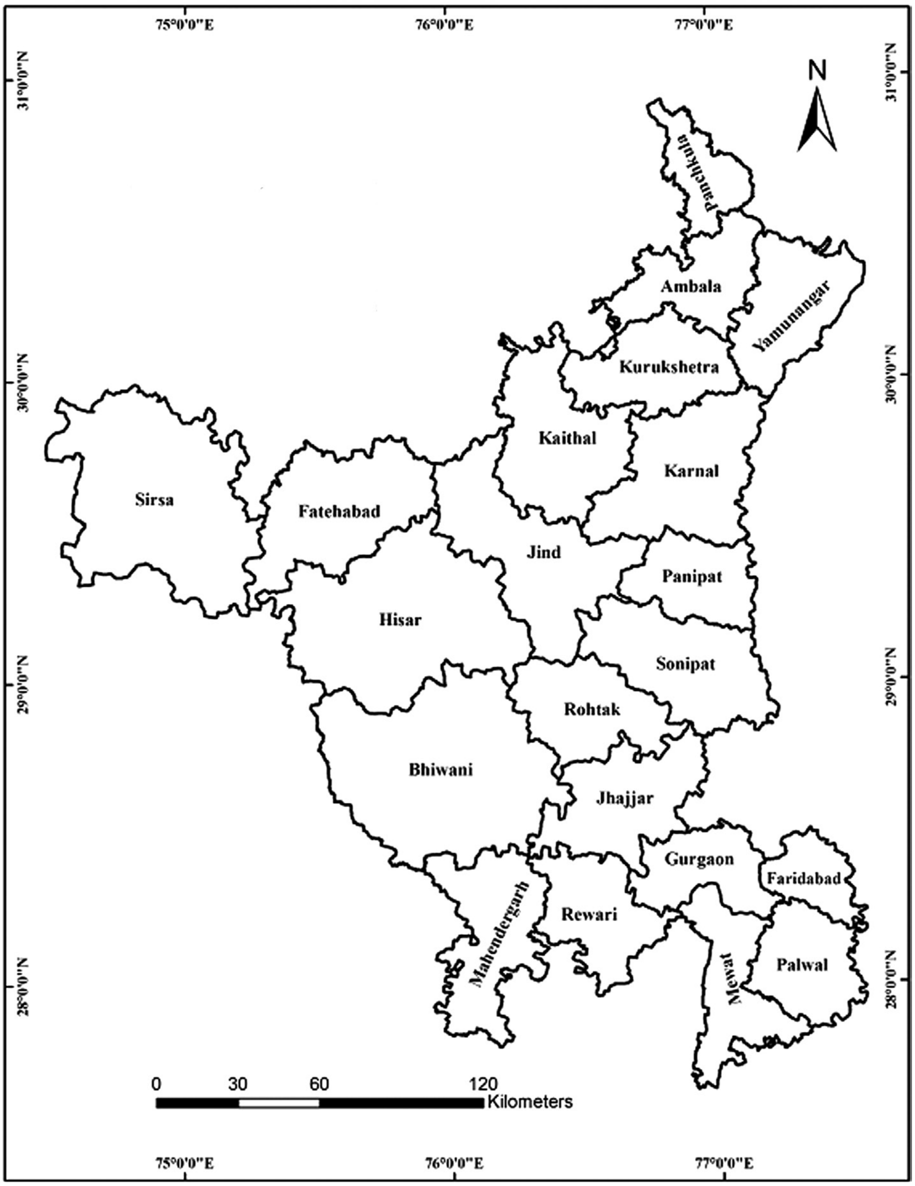

Fig. 1

Haryana having a geographical area of 44,212 km^2 with 21 districts is predominantly an agrarian state (Fig.1). Green revolution has changed the scenario of agriculture in Haryana. Haryana state with only 1.3 percent of the country's geographical area and 2.5 percent of its cultivated area presently accounts for 6.9 percent of the India's food production (Anonymous, 2012). Soon after its inception in 1966, the highest priority was accorded to agriculture. Measures were taken to expand and modernize the irrigation system in the shortest possible time. Consequently, the net irrigated area expanded two fold (1.3 to 3.0 M ha), resulting in the increased food production from 2.6 to 18.3 million tones in 2011-2012 in the process of exploiting various resources. Irrigation facilities increased from 1.29 million ha to 3.1 million ha and number of minor irrigation units 0.20 million to more than 0.73 millions. Besides, the demand for other uses, such as domestic, industries, forestry and livestock is about 2×10^9 m^3/year. The phenomenal development in agriculture and irrigation facilities led to several complex problems such as rise and fall in groundwater table and its quality deterioration. These problems have threatened the sustainability of irrigated agriculture in the state. Therefore, the major objectives of this study are to identify the reasons of falling groundwater level and to suggest the suitable strategies for its management in the state of Haryana.

Table 1 Haryana: Water Resources

Particulars	**Water Available (BCM/Yr)**
Net annual groundwater availability	8.63
Annual groundwater draft	9.45
Draft for irrigation	9.10
Draft for domestic and irrigation	0.35
Annual replenishable groundwater resources	9.31
Recharge from rainfall (monsoon)	3.52
Recharge from other sources (monsoon)	2.15
Recharge from rainfall (non-monsoon)	0.92
Recharge from other sources (non-monsoon)	2.72
Natural discharge during non-monsoon season	0.68
Projected demand for domestic and industrial uses up to 2025	0.60
Groundwater availability for future irrigation	-1.07
Stage of groundwater development (%)	109

Source: india-wris.nrse.gov.in/wrpinfo/?tittle=Ground_water_resources

Current Status of Water Resources

The current status of water resources in the state can be viewed in terms of supplies and demand for agricultural and non-agricultural activities. Based on the reports of Ministry of Water Resources the net water available is 8.62 billion cubic meters (BCM) and net water draft is 9.45 BCM per year in Haryana, thus leaving an annual deficit of 0.82 BCM (Table 1). About 37 percent of the groundwater is of good quality, 8 percent marginal and 55 percent poor quality, whereas 20 percent of the poor quality water is saline, 35 percent sodic and 45 percent is saline sodic. Generally, the shallow groundwaters are of better quality than deep groundwaters. In order to meet the crop demand the groundwater is overexploited through shallow and deep tube wells. It is posing a serious threat to groundwater availability in future. The groundwater balance estimates shows that out of 21 districts, 13 fall in 'overexploited category' having groundwater extraction more than 100% of annual replenishment, 5 are classified as 'critical' (stage of development 90-100%) and 3 are in 'safe' category having groundwater draft less than 70% of the annual recharge. Gurgaon, Kurukshetra and Kaithal have the maximum stage of development of more than 200%, whereas Bhiwani, Rohtak and Mewat lie in 'safe' category (Table 2). The long term fall of water table for 1974-2012 reveals that average fall of water table in Haryana was about 20 cm per year (Fig. 2).

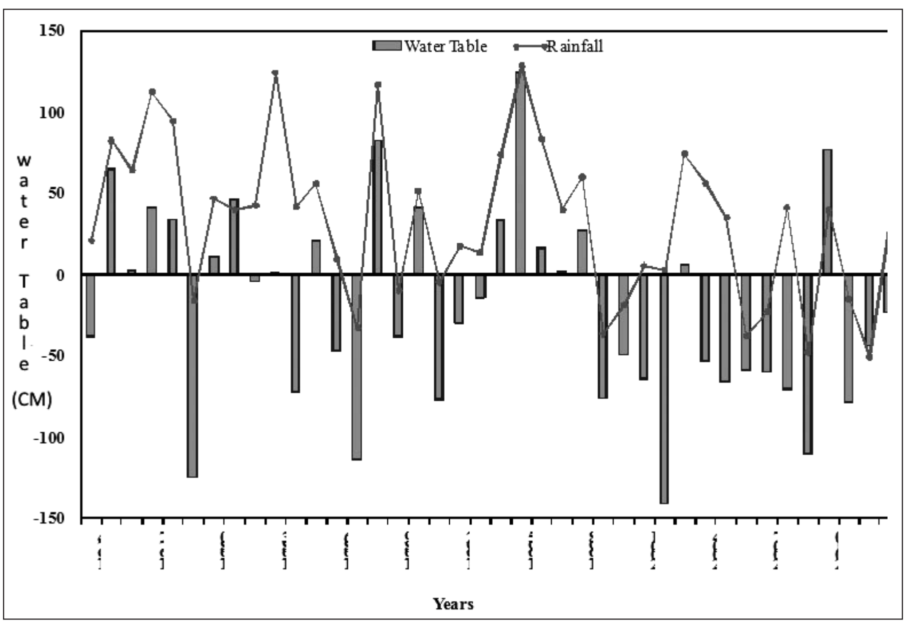

Fig. 2

Table 2 - Haryana: Groundwater Resources and Their Utilizations (2009)

Districts	Net Annual Groundwater Availability	Existing Gross Groundwater Draft for Irrigation	Existing Gross Groundwater Draft for Domestic and Industrial Water Supply	Existing Gross Groundwater Draft for all Uses	Provision for Domestic and Industrial Requirement Supply to 2025	Net Groundwater Availability for Future Irrigation Development	Stage of Groundwater Development (%)	Overall Category of District
Ambala	52244	41583	7710	49293	9040	1621	94	Over exploited
Panchkula	13876	9072	2790	11862	4379	425	85	Critical
Fatehabad	60605	107316	1403	108719	1810	-48521	179	Over exploited
Bhiwani	55138	43068	756	43824	925	11145	79	Safe
Hisar	66249	59836	449	60285	572	5841	91	Critical
Gurgaon	23261	35777	18150	53927	18150	-30666	232	Over exploited
Mewat	21623	13280	1173	14453	1830	6513	67	Safe
Faridabad	20228	14118	2232	16350	2746	3364	81	Critical
Palwal	44771	45892	999	46891	1134	-2255	105	Over exploited
Jhajjar	42718	40751	192	40943	230	1731	96	Critical
Jind	81714	77363	3510	80873	4278	73	99	Critical
Kaithal	50783	101504	6242	107746	6242	-56963	212	Over exploited
Karnal	85905	118899	1244	120143	1244	-34238	140	Over exploited
Kurukshetra	34323	67904	6737	74641	6737	-40318	217	Over exploited
Mahendergarh	21437	22453	388	22841	505	-1521	107	Over exploited
Paniapt	30865	50961	495	51545	495	-20591	167	Over exploited
Rewari	27999	31255	116	31371	131	-3387	112	Over exploited
Rohtak	45017	28446	2297	30743	2662	13909	68	Safe
Sirsa	75452	115634	776	116410	789	-40971	154	Over exploited
Sonipat	77426	90622	3913	94535	4168	-17364	122	Over exploited
Yamunanagar	48199	55077	10215	65292	10471	-17349	135	Over exploited
Total	979833	1170811	71787	1242598	78538	-269516	127	Over exploited

Source: Compiled by authors from Central Ground Water Board District Reports, 2007.

Reasons for Declining Trend of Water Table

The present groundwater scenario in Haryana can be attributed to the following reasons:

Change in Cropping Pattern

After the inception of green revolution in Haryana farmers shifted from low water consuming crops to high water requiring crops such as paddy crop irrespective of soil conditions and rainfall quantity. There has been a phenomenal rise in area under paddy from 3000 km^2 in 1975-76 to 12000 km^2 in 2011-12 (Fig. 3). The irrigation water requirement of this increased paddy crop are fulfilled by groundwater.

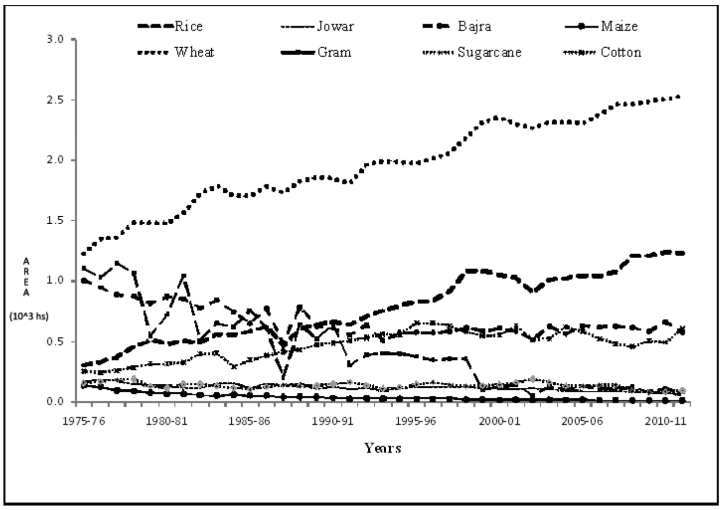

Fig. 3

Increase in Area under Irrigation

Net area under irrigation has increased from 1754 thousand hectares in 1975-76 to 3072 thousand hectares in 2011-2012. Net area irrigated in 1975-76 is 39%, which has increased up to 69.4% in 2011-2012. The net increase of area under irrigation is 1.7 times from the 1975-76 to 2011-2012 and main source of irrigation is groundwater as surface water is less available in the state (Fig. 4). Also, there is an increase in irrigation intensity from 155 to 185 and cropping intensity from 150 to 184, resulting in an increase in abstraction of groundwater over the years.

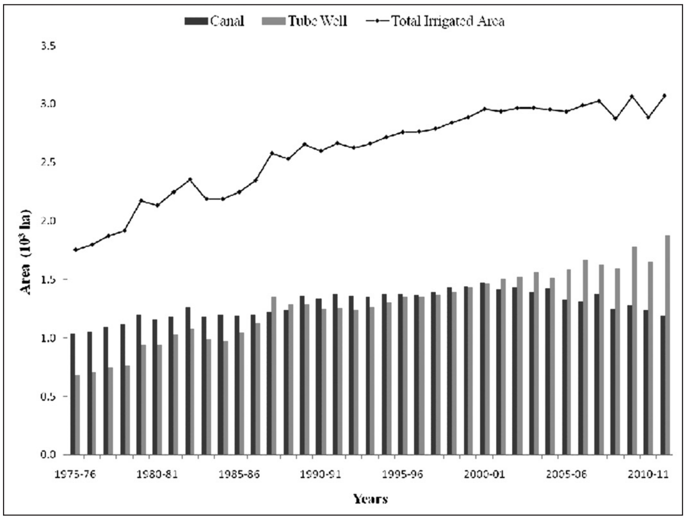

Fig. 4

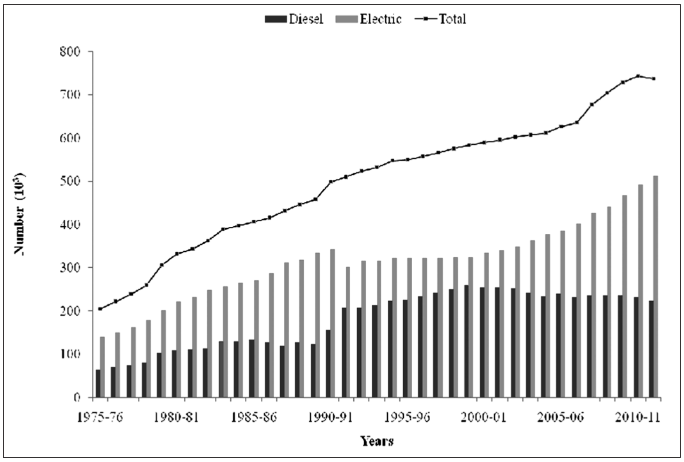

Fig. 5

Increase in Number of Tube wells

Number of tube wells has increased from 0.20 million in 1975-76 to 0.73 million in 2011-2012. This has resulted into excessive over exploitation of groundwater (Fig. 5).

Declining Trend of Rainfall

Long term average annual rainfall in Haryana for a period of 35 years (1975-2010) was observed to be about 544 mm. However, it has declined to 470 mm for the period 2007-12, a reduction of about 74 mm. Meanwhile, rainfall in the state was observed to be concentrated in high intensity short duration storms leading to more surface runoff. An annual decrease in rainfall quantity has also resulted in less natural recharge of the groundwater (Fig. 6). Furthermore, the change in rainfall directly affects the water table behavior. As the amount of rainfall increases, the percolation increases and results into water table recharge and vice-versa (Fig. 2).

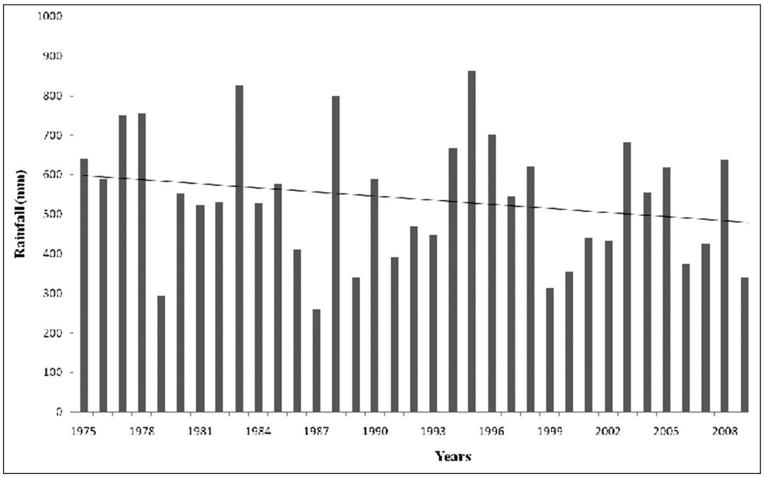

Fig. 6

Declining in Canal Irrigated Area

The percent net area irrigated by canals in the state has decreased from 59% in 1975-76 to only 38% in 2011-2012 (Fig. 4) with the result that dependency on groundwater has increased tremendously to meet food grain production targets.

Lack of Proper Planning of Systematic Groundwater Extraction

Apart from above, groundwater extraction in the state is on the rise to meet the increased population demand in industrial and domestic sector as well. Moreover, property based rights provoke the people towards unregulated abstraction.

Forecast of Groundwater Behaviour

There is a huge gap between groundwater demand and availability in the state as a result of limited water resources. Meanwhile, with the increasing demand of water in agriculture, domestic and industrial sector, the state is heading towards a major water crisis in future. Considering the present trend of fall in water table (Table 3), the future projections are quite disturbing. The water table depth will fall by 18 to 42 m, in different parts of the state by the year 2050 (Vyas, 2001). The cost of replenishing groundwater will be enormous if the same trend continues and it is estimated that the replenishing cost of the resource only in parts of eastern Haryana will likely to be Rs. 275 million (Vashistha et al., 2001). Furthermore, groundwater availability for future irrigation and demand for domestic and industrial sector in the state would be -1.07 and 0.60 BCM/year by the year 2025 (Table 1).

Groundwater Management Options

Until recently full attention has been given to the groundwater development in Haryana

Table 3 - Haryana: Water Table Depth and Fluctuation (1974-2012)

Districts	Average Water Table (m)		Water Table Fluctuation June 1974-2012 (m)	Average Annual Water Table Fluctuation per Year (cm)
	June 1974	June 2012		
Ambala	5.79	10.52	-4.7	-12.4
Bhiwani	21.24	22.42	-1.1	-3.1
Faridabad	6.43	14.64	-8.2	-21.6
Fatehabd	10.48	22.21	-11.7	-30.8
Gurgaon	6.64	23.45	-16.8	-44.2
Hisar	15.47	8.22	7.2	20.1
Jind	11.97	12.14	-0.1	-0.4
Jhajjar	6.32	4.67	1.6	4.3
Kurukshetra	10.21	31.5	-21.2	-56.0
Kaithal	6.28	21.88	-15.6	-41.0
Karnal	5.72	17.19	-11.4	-30.1
Mahendergarh	16.11	44.46	-28.3	-74.6
Mewat	5.56	11.11	-5.5	-14.6
Palwal	5.37	9.06	-3.6	-9.7
Panchkula	7.58	17.02	-9.4	-24.8
Panipat	4.56	16.76	-12.2	-32.1
Rewari	11.75	21.89	-10.1	-26.6
Rohtak	6.64	4.01	2.6	6.9
Sirsa	17.88	17.84	-0.04	0.10
Sonipat	4.68	7.87	-3.1	-8.3
Yamunanagar	6.26	12.75	-6.4	-17.0
Haryana	9.19	16.72	-7.5	-19.8

Source: Compiled by authors

due to its adequate availability. Modern groundwater drilling technologies allowed farmers to exploit the resource extensively to irrigate their crops, which resulted in a spectacular expansion of agriculture and helped people to come out of poverty. However, the management of groundwater could not keep pace with its development and led to overexploitation of the resource. This overexploitation of the resource in Haryana can be addressed by adopting and tracking the following pragmatic and viable solutions.

Adoption of Crop Diversification

Replacing wheat-rice cycle with less water swallowing crops like maize, soybean, groundnut, oilseeds, sunflower, and pulses etc. during *Kharif* and *Rabi* season in the state of Haryana can save substantial quantities of water. Replacement of rice crop with maize crop in 2500 km^2 will save about 325 M m^3 of water (Table 4). Moreover, a separate department of crop diversification need to be set up in the state and officers from departments of agriculture, horticulture, soil conservation, dairy and forestry should constitute this department.

Table 4 - Crop Diversification (Option: Replacement of Rice With)

Crop	**Area (km^2)**	**Irrigation Water Demand (Rice = 73 cm) with Alternative (cm)**	**Water Saved (Mm^3)**
Maize	2,500	60	325
Groundnut	500	50	115
Soybean	500	60	65
Pulses	500	45	150

Source: Aggarwal et al., 2009

Table 5 - Irrigation Efficiencies of Various Irrigation Techniques (percent)

Irrigation Efficiencies	**Methods of Irrigation**		
	Surface	**Sprinkler**	**Drip**
Conveyance efficiencies	40-50 (Canal); 60-70 (well)	100	100
Application efficiencies	60-70	70-80	90
Surface water moisture evaporation	30-40	30-40	20-25
Overall efficiency	30-35	50-60	80-90

Source: Narayanmoorthy, 2004.

Replacement of Long Duration Rice Varieties

Long duration varieties of rice resulted in an increased crop water requirement in the state of Haryana. Therefore, emphasis needs to be given on development of short duration rice varieties and superior quality basmati, having lesser water requirements.

Table 6 - Water Use Efficiency of Crops under Different Irrigation Systems (q/ha/cm)

Crops	Flood Irrigation	Sprinkler Irrigation	Drip Irrigation
Wheat	0.93	1.79	-
Bajra	0.39	1.07	-
Jowar	0.19	0.59	-
Sorghum (kharif)	2.45	4.58	-
Maize (kharif)	1.22	2.01	-
Barley	1.35	3.59	-
Gram	0.37	1.27	-
Oilseeds	0.14	0.31	-
Groundnut (kharif)	0.26	0.47	-
Sunflower (rabi)	0.53	0.96	-
Chillies	0.48	0.89	1.46
Garlic	0.83	1.23	-
Onion	4.29	7.94	2.03
Cotton	0.17	0.24	0.61
Sugarcane	3.23	4.61	21.27
Papaya	0.57	-	3.13
Ash gourd	1.29	-	1.63
Tomato	1.24	-	8.29
Lady's finger	1.87	-	13.15
Brinjal	3.11	-	6.67
Sweet potato	0.67	-	2.37
Radish	0.23	-	1.10
Beet	0.07	-	0.50
Potato	11.79	-	17.21
Watermelon	3.68	-	11.03
Bottle gourd	4.53	-	7.54

Source: Narayanmoorthy, 2004

Water Saving Under Paddy Crop

Paddy in Haryana is sown in an area of about 12340 km^2. Proper scheduling of irrigation (amount and timing) to crops is an important component of water saving technologies. Intermittent irrigation in paddy i.e. 15 days ponding followed by 2 days of drying can result in 25% saving of water. Also, shifting the date of transplanting of paddy from first week of May to third week of June checks the water table decline by 70 cm without any adverse effect on the yield (Hira, 2009; Aggarwal et al., 2009). Likewise, direct seeded rice requires 23% less irrigation water as compared to traditional transplanted rice (Quershi et al., 2006).

Adoption of Modern Irrigation Techniques

Micro irrigation systems (sprinkler and drip) have the potential to increase irrigation water use efficiency (Aggarwal et al., 2009). The usages of these systems can double the irrigated area without constructing any new irrigation projects, reduce energy requirement (electricity), weed problems, soil erosion and cost of cultivation (Narayanmoorthy, 2004). Table 5 shows the efficiencies of different micro irrigation systems and clearly suggests that these systems are more efficient than surface irrigation systems (canal and tube well). Water use efficiency of micro irrigation

Table 7 - Yield Gain and Water Saving of Important Crops under Drip Irrigation

Crop	Increase in Yield (%)	Saving in Water (%)
Sugarcane	15-20	15-20
Maize	10-15	50-60
Pomegranate	20-40	20-30
Lemon	30-40	25-30
Mul berry	10-20	20-25
Guava	40-50	20-30
Green berry	15-20	20-25
Kinnow	30-50	20-30
Cauliflower	20-30	50-60
Bottle guard	20-40	40-50
Cabbage	30-40	50-60
Chili	10-40	60-70
Brinjal	20-30	40-60
Potato	20-30	40-50
Lady finger	25-40	20-30
Tomato	25-50	40-60
Pea	50-60	40-50
Carrot	15-20	40-50

Source: Compiled by authors

systems in relation to conventional irrigation systems (flood and gravity) have been demonstrated with reference to different crops (Table 6). The efficacy of water use is substantially higher under sprinkler and drip irrigation techniques in comparison to flood and gravity irrigation techniques, mainly because of reduction in convenience and distribution losses. Moreover, application of drip irrigation technique on farms saved water without any yield reduction. Table 7 shows the yield gain and water saving of different crops under drip irrigation system.

In the light of above, to avoid aggravating supply-demand gap in irrigation water in the future, it is essential to bring more cropped area under micro irrigation systems in the state. The topography, soil and climate conditions offer huge potential for the application of micro irrigation systems under different crops and the same has been demonstrated in Table 8. This kind of estimate would be useful for making policies, fixing targets and allocation of funds for exploiting the micro irrigation potential in Haryana.

Table 8 - Haryana: Potential Crop Areas Which Can Be Brought under Micro Irrigation (000 ha)

Method	Pulses	Sugarcane	Oilseeds	Cotton	Cereals	Others	Total
Drip	59	140	350	554	-	63	1166
Sprinkler	59	140	350	554	2593	456	4152

Source: Narayanmoorthy, 2004

Table 9 - Comparative Rice Yield and Irrigation Water Savings under Laser and Traditional Land Leveling

Sites	Rice Grain Yield (t ha^{-1})		Average Yield Increased under Laser Leveling (%)	Savings in Irrigation Water under Laser Leveling over Traditional Leveling (%)
	Laser Leveling	Traditional Leveling		
Site 1 a	8.78± 0.33	7.73± 0.21	13.60	26.2
Site 2 a	8.30± 0.46	7.53± 0.39	10.30	-
Site 3 a	7.60± 0.21	7.00± 0.25	8.57	25.0
Site 4 b	8.14± 0.44	7.72± 0.38	5.44	24.1
Site 5 c	7.77± 0.35	7.28± 0.40	6.70	-
Site 6 d	8.43± 0.40	7.35± 0.35	14.6	-

Source: Jat et. al., 2009b

Adoption of Laser Leveling Technique

In recent times, laser leveling technique has been used extensively for water saving in agricultural sector. Its usage has shown overwhelming output in relation to rice grain yield and saving in irrigation water

(Table 9). Therefore, it is suggested that laser leveling should be adopted to save water in rice growing areas of the state.

Adoption of Zero Tillage Technology

Use of zero-tillage drill on one km^2 of land is estimated to save about 0.1 M m^3 of irrigation water (Aggarwal et al., 2009) and can save 13-33% water use (Malik et al., 2002; Jat et al., 2009a). Interestingly, adoption of zero tillage practices over an area of 5,000 km^2 could increase wheat production by 2 billion kilograms, and also can save 5 billion cubic meters of water and 0.5 million cubic meters of diesel each year (Aggarwal et al., 2009).

Adoption of Mulching

Application of straw mulch improves the water use efficiency and helps in water saving by reducing evapotranspiration losses and also increases yields of crops during summer months (Jalota et al., 2000). Mulching of wheat straw under rice-wheat ecosystem can save 25-100 mm of water and number of irrigation by one or irrigation time by an average of 17% in water limiting situations (Zaman and Choudhuri, 1995). Mulching of chilies with paddy straw increased yield by 15% and saved 25% irrigation water, as compared with no mulching in Chilli crop (Sekhon et al., 2008).

Adoption of Raised Bed Planting Technology

Raised bed planting applications have traditionally been associated with water management issues (Govaerts et al., 2007). It has been used since time immemorial by farmers in many parts of the world especially in arid and semi-arid regions where water availability is comparatively low (Jat et al., 2011). Planting of wheat on raised bed has been advocated in India for improving resource use efficiencies, especially water use efficiency. Significant increase in water use efficiency on laser level fields has been reported by several researchers under different soil and climatic conditions (Jat et al., 2009a; Gupta et al., 2003; Jat et al., 2011). Cultivation of wheat crop on raised beds resulted in water savings ranging from 18-25 % as compared with the conventional tilled wheat (Hossain et al., 2001; Hobbs and Gupta, 2003). Planting of potato on both sides of narrow beds saved 20% irrigation water, as compared with the ridge-planting method (Thind et al., 2010). Furthermore, 10-20% higher yields were observed as a result of raised bed planting applications (Thind et al., 2010; Jat et al., 2011).

Artificial Recharging of Aquifers

Aquifer management is considered as most effective way of establishing a balance between discharge and recharge components. This practice is widely used in industrialized countries such as Germany, Switerzerland, United States of America, Netherlands and Sweden etc. Declining groundwater in the state can also be recharged by constructing artificial groundwater recharge structures. However, several artificial recharge structures such as, percolation tanks, ponds, contour bunding, injection wells, recharge pits and shafts have been constructed to augment groundwater resources in the state. These artificial recharge structures provide about 1072 and 1270 ha m monsoon and non-monsoon recharge, respectively in the state (Table 10). Therefore, more recharge

Table 10 - Haryana: Number of Structures for Artificial Recharge and Their Monsoon and Non-monsoon Recharge

Districts	No of Recharge Structures	Monsoon Recharge (ha-m)	Non-monsoon Recharge (ha-m)
Ambala	720	41.41	3.61
Fatehabad	191	32.54	-
Hisar	260	74.30	64.07
Jhajjar	375	82.00	96.84
Jind	922	256.5	523.69
Kaithal	292	87.91	152.12
Karnal	718	129.73	159.13
Kurukshetra	163	44.84	34.82
Panipat	364	97.06	119.31
Panchkula	160	6.91	-
Rohtak	377	97.2	113.4
Sirsa	487	99.87	-
Yamunanagar	553	22.42	3.75
Haryana	5582	1072.69	1270.74

Source: Central Ground Water Board, 2007

structures need to be constructed in the state and particularly in the districts namely Gurgaon, Mewat, Sonipat, Mahindergarh, Rewari, Bhiwani, Faridabad and Palwal to replete the groundwater resources.

Promotion of Rooftop Rainwater Harvesting

Rooftop water harvesting for groundwater recharge has given new hopes to overcome the groundwater problem (Singh and Singh, 2002). Farmers in the state should be encouraged to harvest rainwater and adopt watershed management strategies to both improve the productivity of rain fed systems and reduce the demand of groundwater. Many fragmented efforts in Haryana have been made in the past in several areas. However, there is a need to develop comprehensive policy at the government level to ensure continuity in this regard.

Ownership and Groundwater Legislation

The absolute ownership concept, embodied in the Indian Easement Act 1882, has paved way for unlimited extraction of groundwater by landowners in the state. This act leads to misuse of the resource among landowners. To counter the 1882 act, a new act on groundwater development, protection and management was drafted in 1997 to check the unlimited withdrawal of groundwater. This new act needs to be enforced in letter and spirit by the state government to check the unrestricted draft of the groundwater. Likewise, principle of 'self regulation' on behalf of landowners will be the best strategy to check the injudicious extraction of groundwater.

Research and Development

There is an urgent need for planning and implementation of the research and development activities in the state for optimum utilization and management of groundwater resources. These include identification of suitable areas for recharge measures, conjunctive use of groundwater, efficient tube well designs and conservation of groundwater. Public awareness and education is most essential through research and development activities and demonstration (Jha, 2007).

Pricing of Groundwater

Water supply projects (domestic, industrial and agricultural) are instruments of agricultural output, economic development and social benefit. However, undue advantage of these projects is being taken by the affluent class of the society (e.g. affluent farmers). This affluent class enjoys 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, this affluent class indiscriminately extracting groundwater without paying any heed to environmental or social consideration (Singh and Singh, 2002). Hence, there is a need to allocate water at a cost commensurate with demand among various users as present pricing structure does not provide necessary incentives for its efficient use. Pricing of groundwater can play a very important role in increasing water use efficiency in the state.

Conclusions

Groundwater accounts for almost half of the irrigation requirement of Haryana and have contributed significantly in the agricultural development. There is clear evidence that groundwater is being overexploited, yet about 20000 of additional tube wells are being installed every year. In the rain fed areas of the south-west, farmers are pumping groundwater from depth of about 50 m and its depletion is now a fact in all districts of state. Therefore, to achieve a sustainable utilization of groundwater resources, a balanced development and management mechanisms is urgently required involving users, planners and policy makers at all levels (participatory approach). Interestingly, farmers should be educated to grow high value addition crops with the expensive groundwater rather than continuing with traditional wheat and rice crops. This will yield them good incomes and improve their livelihoods. After being well off, farmers would start adopting more efficient groundwater irrigation systems. Likewise, separate strategies should be developed for large commercial farmers and for small poor farmers who are totally dependent on groundwater for protecting their livelihoods. Cropped area for different crops should be fixed on the basis of requirement and the availability of water resources. Notwithstanding, if attention to groundwater management is not given now, Haryana will be facing a major water crisis in the coming years. Realizing the importance of groundwater development and management the government of Haryana has started several corrective and protective measures besides introducing the groundwater development, protection and management act, way back in 1997. Now the state government is needed to aim and act on these lines on priority to protect the groundwater environment in relation to all developmental activities. Artificial groundwater recharge and establishment of groundwater monitoring stations are some important schemes launched by the state government. However, to make these schemes result oriented strong political, administrative and technical will is needed. Furthermore, there is urgent need to create awareness among the users so that groundwater development and management can be a people's programme in Haryana.

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Omvir Singh
Associate Professor

Amrita
Research Scholar
Department of Geography,
Kurukshetra University,
Kurukshetra-136119, India
Corresponding Author