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IRRIGATION DEVELOPMENT AND DEPLETION OF GROUNDWATER RESOURCE IN SOUTHWESTERN HARYANA

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Abstract

Declining availability of water is one of the foremost environmental challenges in the 21st century in India. Due to increased demand of water for food production, continuous fluctuation in precipitation and the drying up of rivers, the demand of groundwater for irrigation is increasing year by year. This paper attempts to provide an insight into the process of irrigation development, its spatio-temporal pattern and consequences of groundwater overexploitation over last three decades in southwestern Haryana. The study reveals that the expansion of irrigation in the region started in 1980s. Spatial diffusion and changing system of irrigation have had some positive impact on the development of agriculture in the study area. But over reliance on groundwater irrigation in the region has resulted in depletion of groundwater resources at an alarming rate which is a matter of great concern. On the other hand, rising water table in some canal commands in northern parts of the study area due to intensive irrigation has caused waterlogging and soil salinity. This situation certainly calls for the concerted efforts for management and conjunctive utilization of surface and ground water resources for sustainable agricultural development in southwestern Haryana.

Introduction

Groundwater is considered as the most dependable source of irrigation. It has played a major role in increasing the food production and achieving food security throughout the world. It is also supposed to help in creating stable socio-economic conditions (Moench, 1992). Declining availability of water is one of the major global environmental challenges for the next century (Postel and Vickers, 2004). But in most regions groundwater resources are shrinking day by day and the volume of groundwater has got depleted during the past 100 years (Leonard and Kendy, 2005). Adequate and reliable water supplies are not available to support current agricultural, industrial, and domestic uses, and future water requirements are predicted to be increased by manifold (Jury and Vaux, 2005). Eighty five per cent of total human consumptive water use is for agriculture and food production which may soon be limited by water availability (Gleick, 2003). Intensive development of groundwater resources for irrigation has resulted in notable decline of the water table in many areas of the world (Kromm and White, 1992; Changming et al., 2001). Decline in groundwater table is featured at the top of the list of adverse environmental effects caused by current water management practices, followed by decline in

groundwater quality, waterlogging and salinization mostly due to inadequate drainage, increase in irrigation cost and land subsidence (Shah et al., 2000).

The Planning Commission of India (2007) in its report of the Expert Group on Ground Water Management and Ownership takes stock of the availability and use of groundwater and outlines the extent, causes and consequences of groundwater exploitation. It has found that the groundwater resource in India is under severe stress. The country draws out an estimated 231 billion m^3 of water from the ground annually, the largest amount in the world. The rate of extraction far exceeds the rate of replenishment in many blocks, leading to a progressive lowering of the water table in various regions of the country. In the decades since independence, official statistics indicate that the area irrigated by groundwater in India has grown in size (Moench, 1992a; World Bank, 1998). In 1950 groundwater accounted for less than one-fifth of country's irrigated areas. The proportion of groundwater irrigation has increased sharply during last five decades. At present more than 60 per cent irrigated area in the country is under tubewell irrigation (Dhawan, 1995; Zhen and Routray, 2002; Kettle et al., 2007). This rapid expansion of groundwater irrigation has resulted in significant decline in groundwater levels (Bhatia, 1992; Moench, 1992a; Vaidyanathan, 1996; Janakarajan and Moench, 2006; Bhalla, 2007). But over exploitation of ground water resources is taking place in many areas. It has been estimated that declining water levels could reduce India's harvest by 25 per cent or more (Mustafa et al., 2007).

Haryana is counted among agriculturally developed states of India. The developmental process of the agriculture in the state is co-terminus with the initiation of 'Green Revolution', whereby the seed-cum-fertilizers package technology clubbed with development of irrigation ushered an era of economic growth and development in the state in mid 1960s. But the southwestern part of the state, the area of the present study largely remained in the shadow zone of 'Green Revolution'. This region could not be sufficiently benefited by irrigation development due to lack of surface water resources (tail ends of canal commands) and limited ground water resources. Seasonal streams and water bodies in the region also do not provide enough fresh water for surface irrigation or replenishment of groundwater. But the farmers of this water scarcity region also started large-scale exploitation of groundwater resources for irrigation during 1980s. Consequently, the pressure on ground water resources in particular has increased due to introduction and expansion of sprinkler irrigation and installation of deep boring tubewells. The large scale mining of groundwater has resulted in rapid depletion of groundwater resources. As a consequence about 50 per cent blocks in this region fall under over exploited category (Ground Water Cell Govt. of Haryana, 2009). Whereas, canal irrigated areas in northern parts of region have experienced rise in water table which has led to waterlogging in some areas. The present study makes an attempt to understand the dynamics of groundwater depletion in the region. The findings of this study shall contribute to a greater understanding about groundwater resources of southwestern Haryana in the context of sustainability and vulnerability of tubewell irrigation.

Objectives of the Study

The present study pertains to southwestern Haryana, where the depletion of groundwater resources has threatened the long term sustainability of agriculture. The study aims to realize followings objectives:

1. To evaluate the process of development of irrigation over last three decades in southwestern Haryana.
2. To assess the impacts of irrigation development on the groundwater resources in the region.
3. To analyze the spatio-temporal pattern, dynamics and consequences of groundwater overexploitation in the study area.

Data Base and Methodology

The present study makes use of secondary data to assess the changing agricultural scenario and groundwater overexploitation in southwestern Haryana. The secondary data on area under irrigation, crops, crop production and agricultural inputs have been compiled from the Statistical Abstract of Haryana, Economic and Statistical Organization, Planning Department, Government of Haryana, Panchkula. The indicators of irrigational and agricultural development have been computed for the triennia 1965-68, 1979-82 and 2004-07. The triennia averages have been taken to minimize the yearly fluctuation in area and production of crops. The tables based on above mentioned data source provide the comparison of the indicators across the periods, i.e. mid 1960s, early 1980s and first decade of 21st century.

The data related to groundwater depth, area under waterlogging, blockwise statistics and information about status of blocks with respect to depth of water table (over exploited, critical, semi-critical and safe) and rainfall have been collected from Central Ground Water Board (Northern Region), Chandigarh and Ground Water Cell (GWC), Department of Agriculture, Panchkula, Haryana. The overview and situation of groundwater in southwestern Haryana have been presented by constructing trend graphs of water depths for the period 1974-2007. The proportion of area under different water depths in the districts of southwestern Haryana for 1974-1987 and 1974-2007 has been depicted with the help of table. To depict the spatial pattern of groundwater depth in the region, isopleth technique has been used for mapping. Observations from 600 wells (485 observation wells, 77 pezometers and 38 key observation wells) from Ground Water Cell, Panchkula have been used to prepare water table depth and fluctuation maps in Arc GIS 9.3 using geo-statistical analyst extension. An Ordinary Kriging estimator has been used to model water table elevation.

Study Area

The study area is southwestern region of Haryana state which is largely a soil moisture stressed region because of scanty rainfall and paucity of water resources for irrigation. It comprised of seven districts namely Rohtak, Bhiwani, Jhajjar, Gurgaon, Rewari, Mahendergarh and Mewat (newly formed). Since, the statistics on agriculture and groundwater for the Mewat district are not available separately for the study period therefore, it is clubbed with Gurgaon (old) district. It has a geographical extension between 27° 30' 35" to 29° 0' 5" north latitude and from 76° 45' 30" to 78° 30' 50" east longitude (Fig. 1). As per Census of India 2011, study area is comprised of 38 CD blocks and 2357 inhabited villages. It shares boundaries with great expanse of Rajasthan in the south and west. It has a total land area of 14,564 km2 and a population of 80, 65,999 with average population density of 554 persons per square km. Southwestern Haryana is largely a dryland where irrigation resources are limited. Presence of inland stream, sandy plain, shifting sand dunes, lack of vegetation, dissected

upland tract, denuded rocky hill ranges and their outcrops support an ensemble of terrain features truly associated with semi-arid and arid environment. Most of the study area lies below 300 meters of MSL. The presence of Arawali hills and sand dunes makes it an undulating and rolling topography in the districts of Bhiwani, Rewari, Mahendergarh, Mewat and northwestern tract of Gurgaon district. The study area has an annual average temperate of 24°C. Hence, temperature is not a limiting physical factor in crop production. The high annual range of temperature facilitates three cropping seasons in the region. The *Kharif* season coincides with the summer rainy (southwest Monsoon) season from June to September. The *Rabi* season extends from October to March. The *Zaid* crop season extends from April to May during dry period. The area has a subtropical continental monsoon type climate. Annual precipitation is about 459 mm which is unevenly distributed. Southwest monsoon brings maximum showers (75 per cent of total annual rainfall) during summer. The *Rabi* season is mostly dry and hence experiences soil moisture deficit. In *Rabi* season the cultivation of crops is done by irrigation. Southwestern Haryana did have a sluggish agricultural growth till 1980s. But the sudden increase in number of tubwells and diffusion of sprinkler irrigation induced agricultural development during last two decades of 20th century.

Results and Discussion

Irrigation Development

Southwestern Haryana experiences perpetual soil moisture deficit throughout the

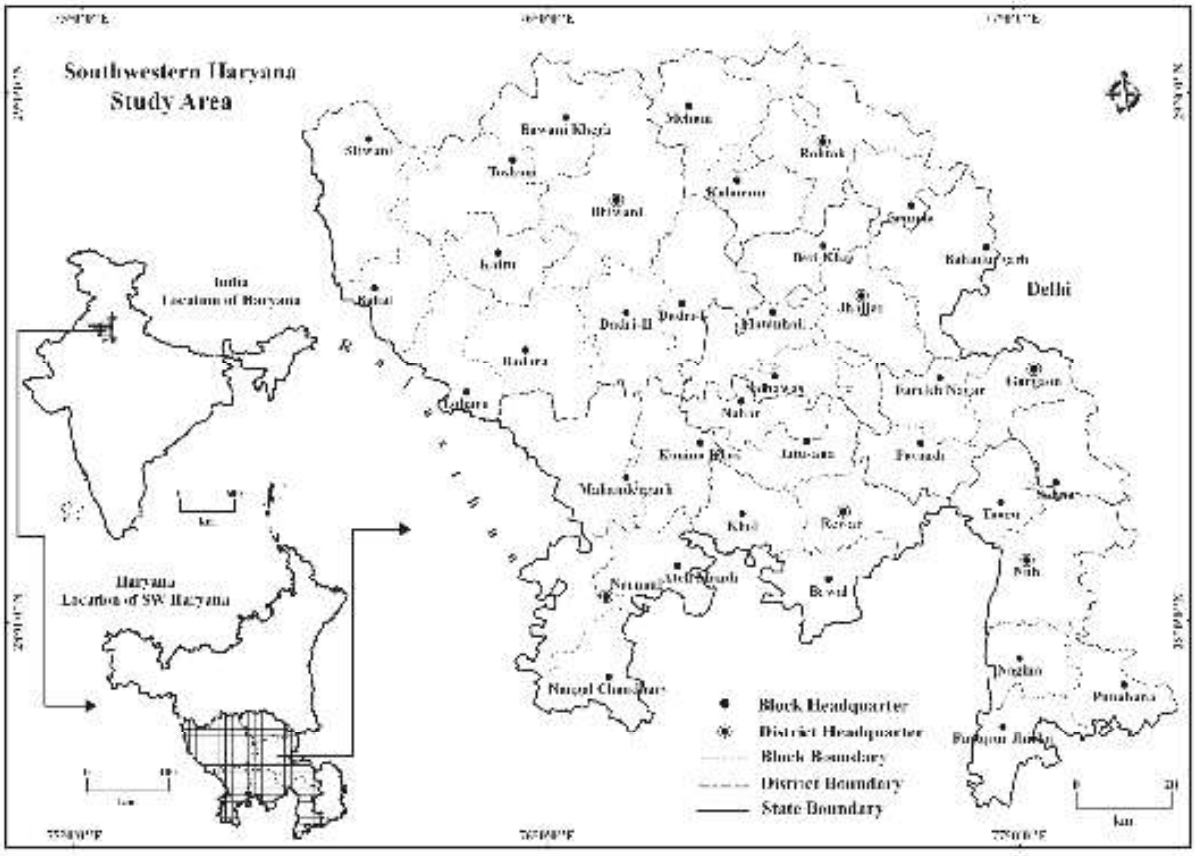


Fig. 1

year as it receives merely 400 to 500 mm rainfall annually. Hence, development of irrigation facilities is crucial for agricultural development in the region. Some efforts have been made in this direction resulting in utilization of surface and groundwater resources. The proportion of irrigated area is a very significant indicator of level of agricultural development. The region has experienced increase in proportion of irrigated area since 1965-68. The proportion of net irrigated area has increased from 27.10 per cent in 1965-68 to 73.43 per cent in 2004-07, but still this is lower than the state average of 86.0 per cent (Table 1). There is also a significant spatial variation in level of irrigation development in the region. It is evident from the table 1 that the southern and western parts of the region comprising the districts of Gurgaon and Bhiwani have low level of irrigation development.

Overall, the share of tubewell irrigation in the region has increased consistently particularly since 1980s.Table 1 also shows that canals have made significant contribution in development of irrigation in the northern and northwestern part of the region. In Rohtak district canals accounted for irrigating more than 67 per cent of total cropped area during 2004-07. Jhajjar and Bhiwani districts are other beneficiaries of canal irrigation. In the sand dune infested plain of Bhiwani district the lift canal system is the only source of irrigation due to saline underground water. The southern districts of the region, namely, Gurgaon, Rewari, and Mahendergarh have very low share of canal irrigation. These are dominantly tubewell irrigated districts where irrigation is largely confined to Rabi season. In Mahendergarh and Rewari districts the proportion of tubewell irrigation is about 84 per cent (Table 1).

Table 1
Southwestern Haryana: Indicators of Irrigation Development

District	Per cent Irrigated Area (NAI as a percentage of NSA)			Per cent Area Irrigated by Canals			Per cent Area Irrigated by Tubewells		
	1965-68	1979-82	2004-07	1965-68	1979-82	2004-07	1965-68	1979-82	2004-07
Rohtak	41.40	59.60	86.80	31.50	37.80	67.70	9.60	21.80	19.10
Gurgaon	20.60	39.10	53.90	4.40	4.00	9.70	9.20	34.50	44.20
Mahendergarh	10.80	38.20	85.20	4.20	1.30	1.40	5.10	36.80	83.80
Bhiwani	DNA	31.50	69.60	DNA	22.80	40.33	DNA	8.50	29.30
Jhajjar	DNA	DNA	80.90	DNA	DNA	42.40	DNA	DNA	38.50
Rewari	DNA	DNA	84.50	DNA	DNA	1.00	DNA	DNA	83.40
Southwestern Haryana	**27.10**	**42.40**	**73.43**	**15.00**	**19.20**	**30.30**	**8.50**	**22.50**	**44.40**
Haryana	**35.30**	**61.20**	**86.00**	**27.10**	**32.80**	**40.40**	**6.60**	**27.60**	**43.70**

DNA: Data not available; NAI: Net Irrigated Area; NSA: Net Sown Area.
Source: Compiled and computed by authors from Statistical Abstract of Haryana.

The other indicator of irrigation development, proportion of gross irrigated area to gross cropped area has also increased three fold, i.e. from 22.83 per cent in 1965-68 to 66 per cent in 2004-07 (Table 2). But this is quite low in comparison to the overall level of irrigation (85 per cent) in the state. The ratio between gross irrigated area and net irrigated area expressed in percentage may be taken as an indicator of intensity of irrigation. It indicates as how intensively the available water resources are being utilized for irrigation. In 1965-68, intensity of irrigation in southwestern Haryana was low (120 per cent), which

Table 2
Southwestern Haryana: Indicators of Agricultural Development

S. No	Indicators	Southwestern Haryana			Haryana		
		1965-68	1979-82	2004-07	1965-68	1979-82	2004-07
Parameters of irrigation development							
1.	NAI as a percentage of NSA	27.10	42.40	73.43	35.30	61.20	86.00
2.	GAI as a percentage of GCA	22.83	37.71	66.00	36.20	61.23	85.00
3.	Irrigation intensity (per cent)	120	131	152	139	151	180
Parameters of biological inputs							
4.	Per cent foodgrains area under HYV seeds	DNA	55.32	90.00	DNA	77.30	89.10
5.	Consumption of chemical fertilizers (kg/ha)	DNA	19.30	159.02	DNA	65.10	311.23
6.	Use of pesticides (kg/ha)	DNA	DNA	0.72	DNA	DNA	1.40
Parameters of mechanization							
7.	Number of tractors (per 00' ha)	DNA	1.00	6.00	DNA	2.00	7.00
8.	Number of tubewells and pumping sets (per 00'ha)	DNA	8.00	15.00	DNA	9.00	17.0
Level of cropping intensity and agricultural productivity and others							
9.	Proportion of NSA to geographical area	79.00	80.20	78.80	77.90	81.80	80.20
10.	Proportion of foodgrains acreage to GCA (per cent)	80.40	78.69	57.75	73.47	72.56	64.84
11.	Proportion of cereals acreage to GCA (per cent)	57.62	60.98	53.84	49.46	57.35	62.83
12.	Proportion of fine cereals acreage to GCA (per cent)	16.62	20.44	28.57	20.72	37.23	51.72
13.	Proportion of coarse cereals acreage to GCA (per cent)	41	40.54	25.27	28.74	20.12	11.11
14.	Proportion of pulses acreage to GCA (per cent)	22.78	17.71	3.91	24.01	15.21	2.01
15.	Cropping intensity (per cent)	139	146	171	135	149	183
16	Agricultural productivity (Rs./ha)	12390	11165	29987	12156	19006	42451

DNA: Data not available; NAI: Net Area Irrigated; NSA: Net Sown Area; GAI: Gross Area Irrigated; GCA: Gross Cropped Area; HYV: High Yielding Variety.
Source: Compiled and computed by authors from Statistical Abstract of Haryana.

increased to 131 per cent in 1979-82. It showed significant increase during next two and half decades and was recorded 152 per cent in 2004-07. However, compared to the state average (180 per cent) the irrigation intensity is also low in the region (Table 2).

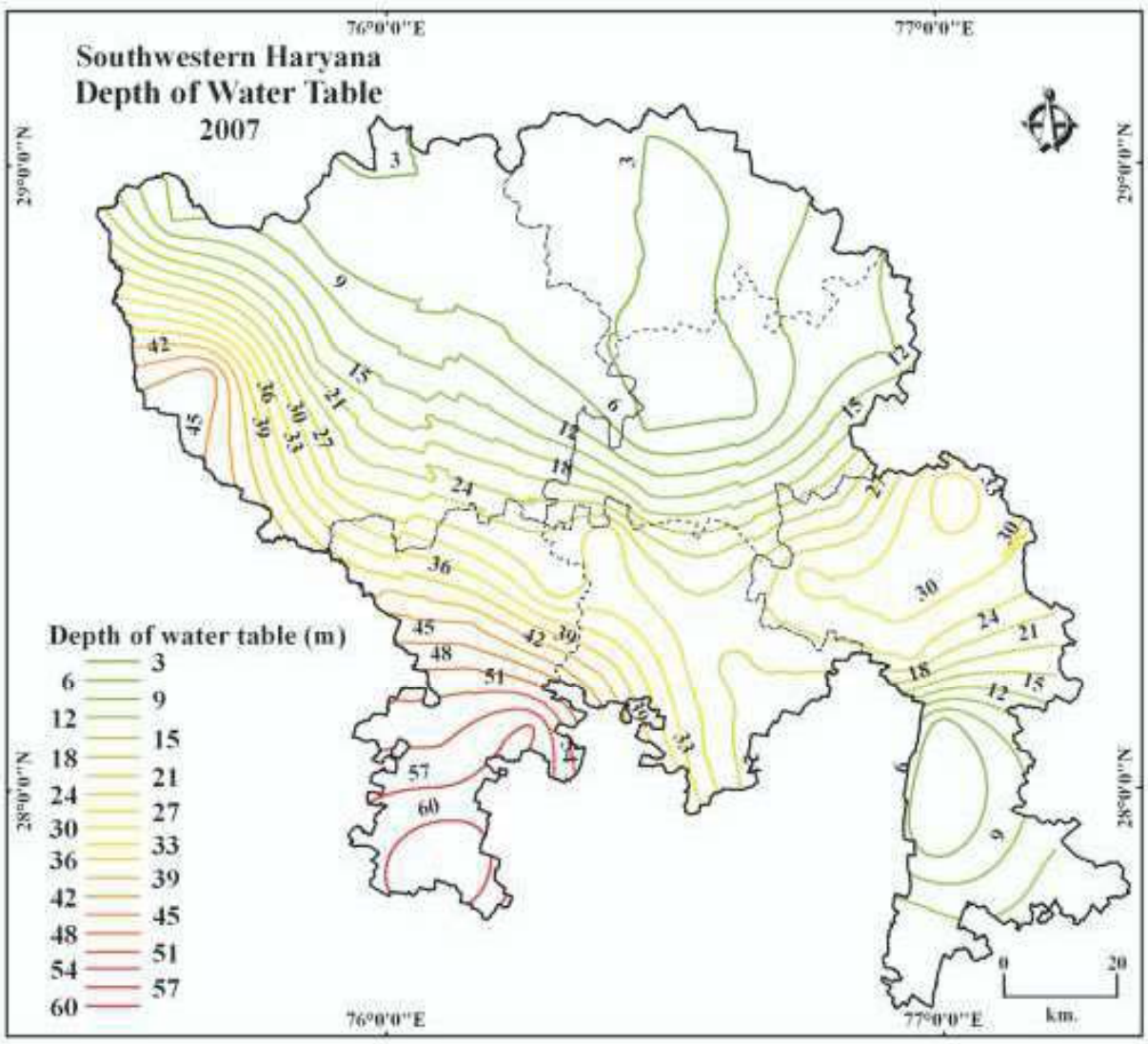
It can be fairly inferred that irrigation expansion and changing system of irrigation have had some positive impact on the development of agriculture in southwestern Haryana particularly since 1980s. This is reflected by the quantitative increase in parameters of agricultural development such as consumption and use of bio-chemical and modern agricultural inputs, cropping pattern, cropping intensity, agricultural land productivity etc. (Table 2). This also establishes that the process of agricultural development in the region is linked to the expansion process of irrigation and its constraints.

Depletion of Groundwater Resources

Increasing use of groundwater for irrigation purposes in southern part of the study area has resulted in water level decline in both shallow and deep aquifers. Fig. 2 depicts the ground water level scenario in southwestern Haryana. It reveals that the depth of water table varied across different parts of the study area. The data of groundwater depth in the region show that the depth of groundwater varies between 2 to 63 m. It reveals that rate of decline of groundwater level also varies across the region. The shallow depth of groundwater level is found in northern and northeastern parts of the study area where water table depth is around 6 m below ground level (bgl). It is attributed to

the continuous recharge from perennial canals. Consequently, in some of the areas in Rohtak, Bhiwani and Jhajjar districts the groundwater level is less than 3 m deep. On the other hand water table has gone as deep as 60 m in some pockets in Mahendergarh district. Other parts of southern Haryana like Rewari and Gurgaon districts also have deep water table and lack fresh water aquifers.

The difference between recharge and withdrawal of ground water causes fluctuations in water level which can be seasonal as well as progressive for longer period. Broadly, the seasonal fluctuations occur due to seasonal variations in rainfall and groundwater utilization. In irrigated areas in India, the lowest level normally occurs during pre-monsoon period and the highest during post-monsoon period. It is evident from Fig. 3 that the study area experienced constant decline in groundwater table over the period 1974 to 2007 except the mid 1970s and 1995 to 1998 when exceptionally good monsoon helped in raising the water table. The average depth of water table in southwestern Haryana has increased from 10.34 m in 1974 to 17.80 m in 2007,



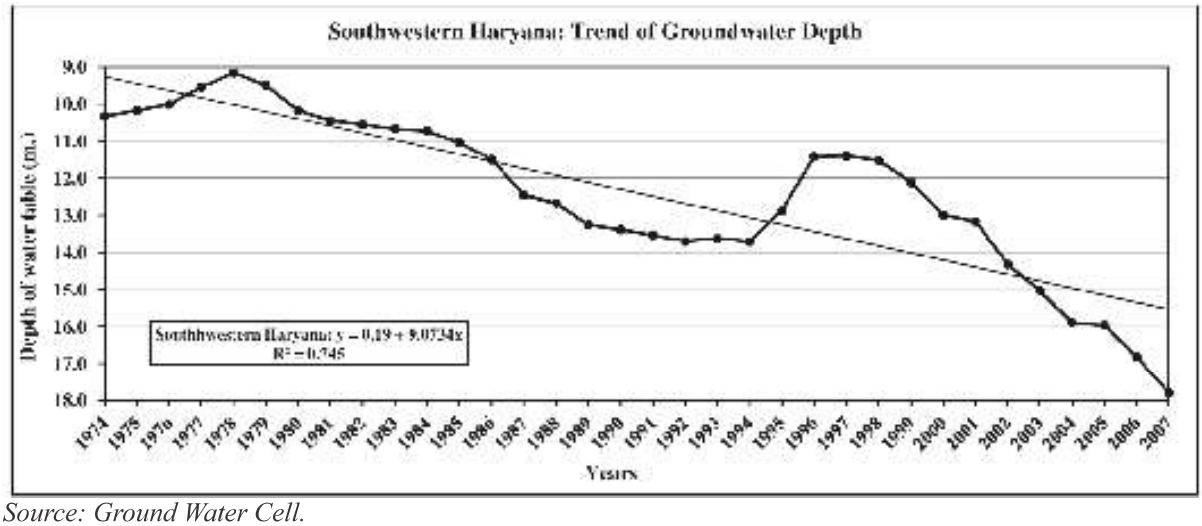
Source: Ground Water Cell.

Fig. 2

indicating an average water table fall of 0.19 m/year. Fig. 4 reveals that the worst affected districts in groundwater depletion are Mahendergarh, Gurgaon and Rewari where the water table depth has fallen by 24.41, 15.23 and 10.0 m respectively over the period 1974 to 2007. The annual rate of water table decline is as high as 0.66 m in Mahendergarh district followed by Gurgaon district (0.44 m/year) and Rewari district (0.21 m/year). Over withdrawal of groundwater for irrigation because of the absence of canal irrigation in large part of these districts is responsible for the sharp decline in depth of ground water table.

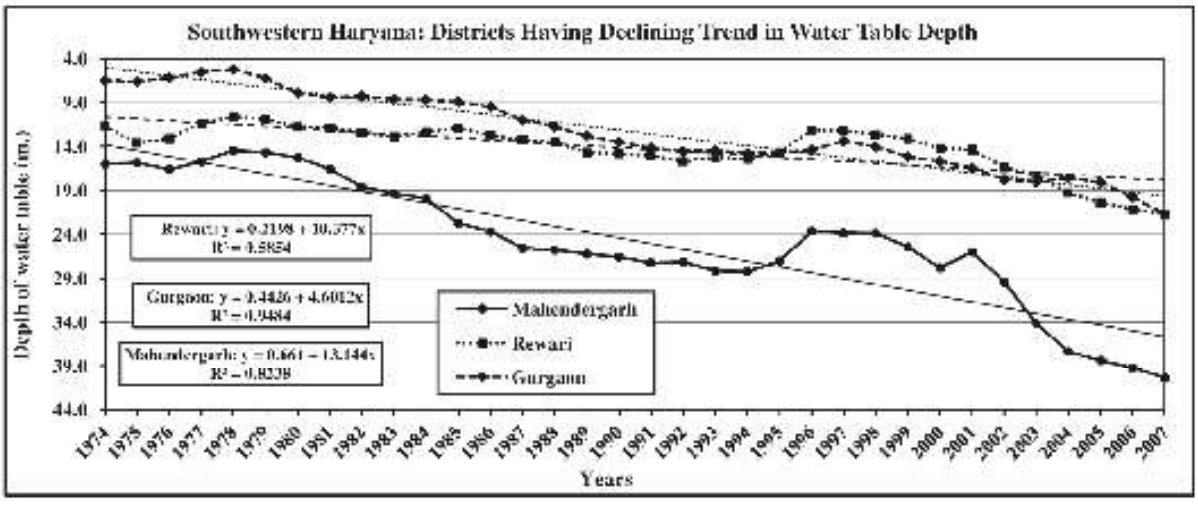
Rising Water Level and Waterlogging

Groundwater situation in the study area has two dimensions. As discussed in preceding section, first is declining water table due to over-pumping of groundwater in fresh water quality aquifer zones. The second is rising groundwater table in areas with low quality aquifers, leading to secondary salinisation and waterlogging. A vast area in north and



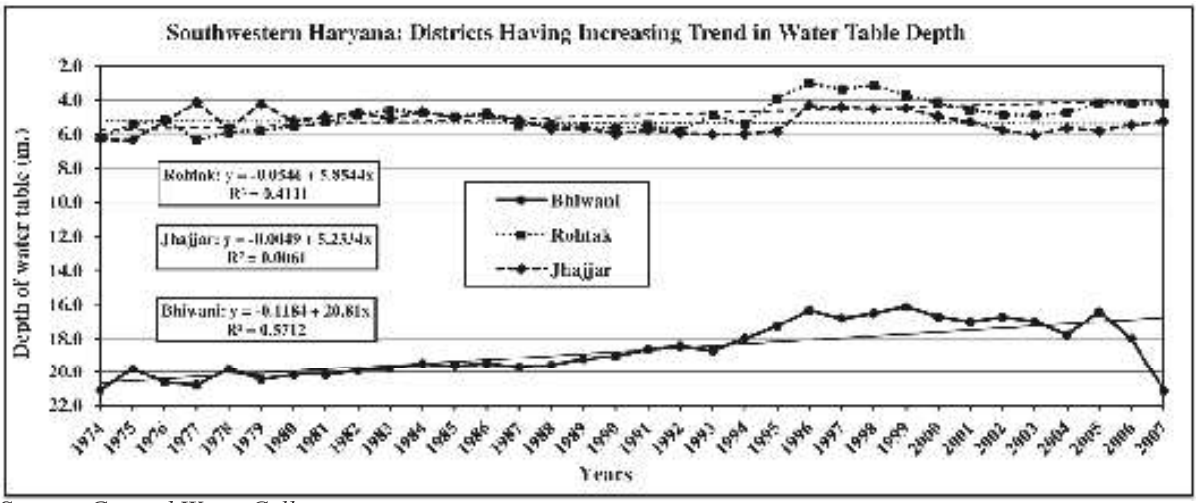
Source: Ground Water Cell.

Fig. 3



Source: Ground Water Cell.

Fig. 4



Source: Ground Water Cell.

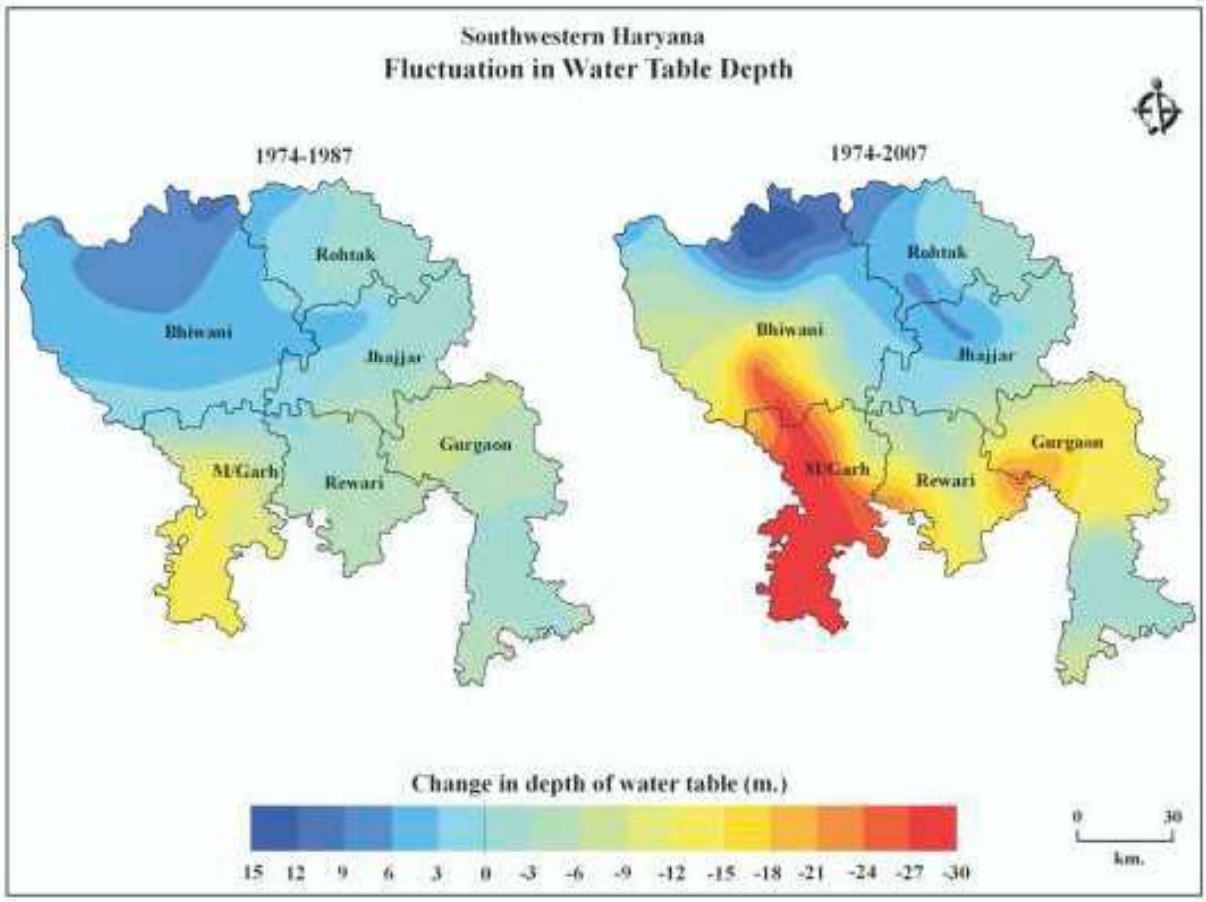
Fig. 5

northeastern part of the study area has experienced consistent rise in water table during last four decades or so owing to intensive canal irrigation and poor drainage network. In Bhiwani and Rohtak districts the water table has risen over the period 1974 to 2007 (Fig. 5). During this period water table in Bhiwani and Rohtak district has risen at an average rate of 0.11 m and 0.66 m per annum respectively. In these districts the rising trend of groundwater table is largely confined to the canal irrigated areas. During above mentioned period the ground water level in Jhajjar district was almost stagnant as shown by the trend equation (y=-0.0049+5.2334x) (Fig. 5).

Water table in the vicinity of root zones of crops affects the growth of plants. The water table within 3 m depth from surface may be termed as waterlogged as water rising up through capillary action mobilizes the soluble salts and results in their concentration in the root zone of plants. Fig. 6 shows that there are some pockets in the region where water table rose sharply during the period 1974 to 2007. These pockets are located in canal irrigated areas of Rohtak, Jhajjar and Bhiwani districts. As a consequence of ascendance in groundwater level, waterlogging has emerged as a serious environmental hazard in canal commands of these districts. The statistics provided by Ground Water Cell show that in southwestern Haryana more than 9 per cent of total geographical area is affected by the problem of waterlogging. Rohtak and Jhajjar districts are most prone to waterlogging where about 39 and 24 per cent area respectively has water table depth less than 3 m bgl (Fig. 7). Shallow water table is also found in some pockets of Bhiwani and Gurgaon districts. Intensive canal irrigation and non-utilization of groundwater resources being saline in nature are the main causes of waterlogging in the areas under cultivation.

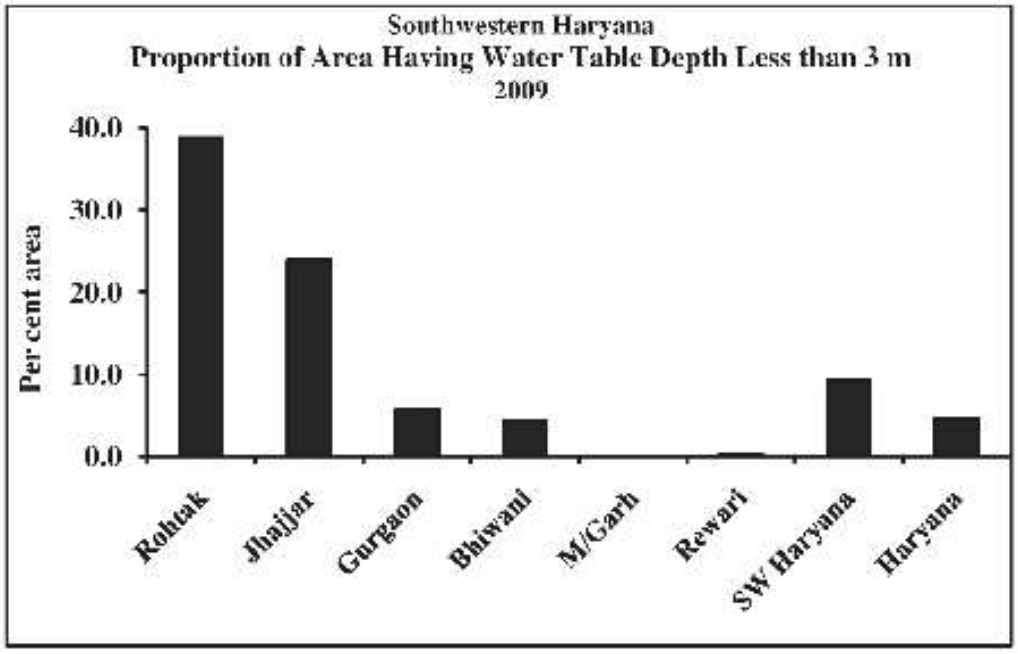
District-wise Pattern of Change in Water Table

As discussed in the preceding section the temporal change in groundwater level in southwestern Haryana varies over the districts. Table 3 and Fig. 6 depict the spatio-temporal pattern of changes in water table. It is also evident from the table that over the period 1974 to 2007, about 71 per cent area in southwestern Haryana experienced fall in the water table. During this period in about one-third area of the region, the water table went down more than 10



Source: Ground Water Cell.

Fig. 6



Source: Ground Water Cell.

Fig. 7

Table 3
Southwestern Haryana: Percentage of Area under Different Categories of Rise and Fall of Water Table

Districts	Time Period	Rise (m)		Fall (m)	
		<10	10-20	<10	10-20
Bhiwani	1974-1987	98.15	1.72	0.13	0.00
	1974-2007	30.09	14.24	34.22	21.45
Rohtak	1974-1987	48.69	0.00	51.31	0.00
	1974-2007	72.19	0.12	27.70	0.00
Jhajjar	1974-1987	37.15	0.00	62.85	0.00
	1974-2007	52.03	0.00	47.73	0.25
Mahendergarh	1974-1987	8.20	0.00	34.65	57.15
	1974-2007	0.00	0.00	5.59	94.41
Rewari	1974-1987	5.24	0.00	94.76	0.00
	1974-2007	0.00	0.00	41.45	58.55
Gurgaon	1974-1987	0.00	0.00	100.00	0.00
	1974-2007	0.00	0.00	46.59	53.41
Southwestern Haryana	**1974-1987**	**43.19**	**0.54**	**48.68**	**7.59**
	1974-2007	**24.77**	**4.54**	**34.61**	**36.08**

Source: Compiled and computed by authors.

m. It shows that the fall in the water table accelerated during last two decades (after 1987). During the earlier segment of the study period (1974-1987) in fact, the water table rose in only 44 per cent area of southwestern Haryana. The acceleration in the deepening of groundwater level particularly in the southern parts of the study area is closely associated with the era of expansion of the tubewell irrigation in the region i.e. since mid 1980s. Fig. 6 reveals that in southwestern Haryana the line joining Siwani-Bhiwani-Jhajjar-Bhadurgarh towns separates the areas of water table decline in south from the areas experiencing rise in water level. The groundwater depletion is the utmost in the extreme southwestern parts of the region (Mahendergarh district). On the other hand, water table rise is found maximum in northern parts of the region, in Bawani Khera area of Bhiwani district.

Gurgaon district (also including present Mewat district) in the region has the distinction of experiencing fall in water table all over its area over the period 1974 to 1987. In about 50 per cent area of the district, the water table has fallen by more than 10 m during 1987-2007. In this district the fall in water table has accelerated since 1987. Fig. 6 shows that area lying south of Gurgaon upto Taoru and Nuh is worst affected by decline in water table.

Mahendergarh district is worst affected in terms of deepening of groundwater level in the region. Whole district (100 per cent) witnessed depletion of groundwater resources over the period 1974 to 2007. This figure is 92 per cent for the period 1974 to 1987. Furthermore, since 1987 in about 94 per cent area of the district the fall in the water table measured more than 10 m. Fig. 6 shows that in a large area in south and southwestern parts of the district the water table decline is as much as 30 m.

Similarly, water table decline has been experienced at almost all parts of Rewari

district over the period 1974 to 2007. About 59 per cent area of the district witnessed the groundwater level decline by more than 10 m. In this district also the decline in water table accelerated during last two decades of study period. The depletion in groundwater is found to be most along Gurgaon border in the eastern and Mahendergarh border in the western parts.

In Bhiwani district, about 56 per cent areas witnessed fall in water table while groundwater level came up in the rest of the area over the period 1974 to 2007. In about 21 per cent area of the district along the border of Mahendergarh district, the water table has fallen by more than 10 m whereas in the vicinity of Bawani Khera in northern part of the district, the water table has risen by more than 10 m. It is pertinent to mention here that the northern part of the district is dominantly canal irrigated while the southern part is largely dependent on tubewells for irrigation. Table 3 and Fig. 6 also bring out the fact that during the period 1974 to 1987 almost whole of Bhiwani district experienced rise in water table. But after 1987 water table declined sharply in the southern parts of the district.

In Rohtak district the water table has risen in about 72 per cent area (mostly in western parts) over the period 1974 to 2007. While in rest of the area of the district particularly in eastern parts groundwater level has declined. However, the rise in the water table in most parts of the district is less than 10 m (Table 3).

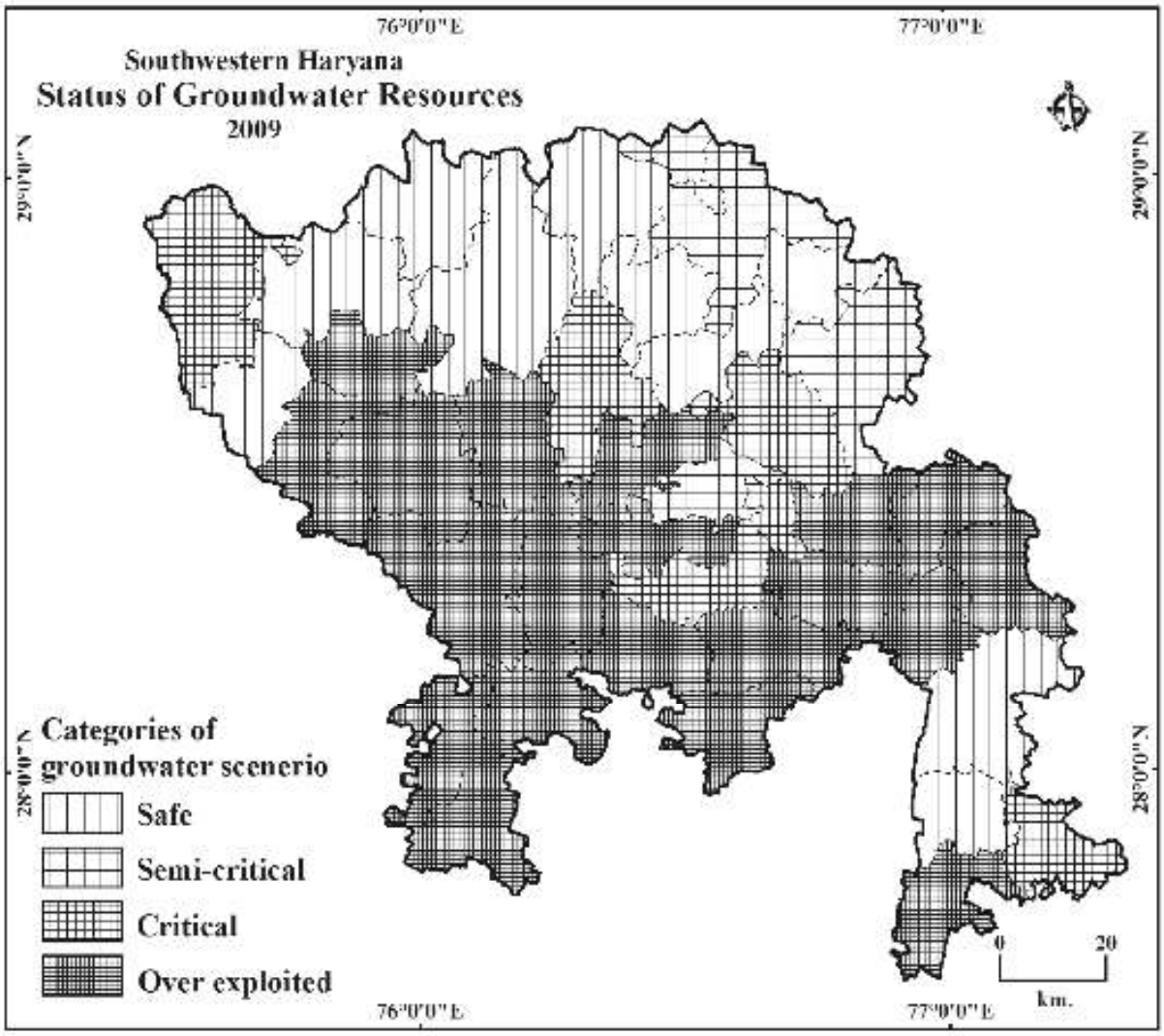
In case of Jhajjar district about 48 per cent area in south and southeastern parts experienced fall in water table up to 10 m over the period 1974 to 2007. While in the same period in about 52 per cent area, mostly in northwestern parts, there has been increase in water table up to 10 m. The decline in the level of groundwater in the district has been sluggish over last two decades (Fig. 6 and Table 3).

Overexploitation of Groundwater Resources

The Central Ground Water Board has estimated the present annual ground water draft in Haryana as 9.45 billion cubic metre (BCM) of which 96 per cent is utilized for irrigation. According to the Report on 3rd Census of Minor Irrigation Schemes (2005), the ultimate irrigation potential from ground water source in Haryana is 1462 thousand ha, whereas 2424 thousand ha land is currently under groundwater irrigation, indicating clearly overexploitation of groundwater resources. It is revealed that in the state, the existing irrigation utilization has exceeded the ultimate groundwater potential. It shows that overexploitation of ground water (exploitation beyond the dynamic resource) is already taking place. However, the degree of over exploitation has varied widely across the state.

Increasing dependence on tubewell irrigation in southwestern Haryana has led to deepening of groundwater and drying of wells. Shallow dug wells have gone dry and farmers now drill multiple bores (tubewells) alongside or in the vicinity of existing dug wells. Consequently, the number of tubewells has increased rapidly. Table 2 shows that over the period 1979-82 to 2004-07, the density of pumping sets, mostly installed in tubewells (number per 100 ha) almost doubled (8 to 15). Consequently the water level has declined sharply affecting the availability and reliability of water supplies for irrigation and other uses. Nonetheless, increasing water scarcity in the region is having adverse impact on agricultural production.

The Central Ground Water Commission (1997) has monitored the depth of groundwater table at the CD block level in Haryana. On the Basis of depletion rate of groundwater resources, the CD blocks have been categorized as overexploited, critical, semi critical and safe.



Source: Ground Water Cell.

Fig. 8

Fig. 8 depicts the spatial pattern of above said categories of groundwater status in southwestern Haryana in 2009. It shows that the extent and degree of overexploitation is most severe in southern part of the study area. Out of 38 CD blocks in the region, 19 blocks (50 per cent) are categorized as over exploited. Most of such blocks lie in Mahendergarh, Gurgaon and Rewari districts. The situation is also dismal in southern parts of Bhiwani district. There are 5 CD blocks (13 per cent) falling in critical category where groundwater exploitation is almost equivalent to recharge. These blocks mostly adjoin the overexploited zone in the south. The remaining 14 blocks (37 per cent) are categorized as semi critical and safe zones. Most of these blocks are located in Rohtak, Bhiwani and Jhajjar districts which also include the areas where groundwater is saline which is not suitable for irrigation. The water table rather has been rising in the northern part of Bhiwani district which is dominantly irrigated by canals. The secular decline in water levels in overexploited and critical areas have led to drying up of shallow wells and the investment on drilling tubewells has reached astronomical level and the poor farmers have already lost out in the race of

chasing the water table. They are forced to either purchase water from others at very high prices or shift to rainfed cropping.

Conclusions and Policy Recommendations

In southwestern Haryana irrigation development in the most part started in 1980s. The northern parts of the region received irrigation through canals, while the southern and western parts experienced irrigation expansion late and mostly through tubewells. This undoubtedly ushered agricultural growth in the region. But the mushroom growth of tubewells during last two decades resulted in excessive exploitation of groundwater. It has been found that in southwestern Haryana the water table is declining at the rate of 0.22 m/year. At the same time the area under canal commands in northern parts experienced rise in water table overshadowing the planned benefit of the irrigation projects. In fact, the mismanagement of groundwater resources is leading to the situation where agricultural development in the region is being hampered in the north by rising water table and in the south by falling water table. Falling water table in the southern parts of the study area is attributed to factors such as overexploitation of groundwater resources for irrigation, stone mining in Aravalli outcrops, sand extraction from riverbeds and construction of *bundhs* on seasonal rivers in neighboring state of Rajasthan.

Keeping the above findings in view, following policy recommendations are suggested for sustainable development of water resources in the region.

1. The prospects of agricultural development in the region are linked to sustainable management of water resources. There is an urgent need of an alternate strategy of agricultural development in tune with the agro-ecological conditions, water availability and natural resource endowment of the region.
2. There should be change in cropping pattern in favour of low water consuming crops. Guar (cluster beans) and other traditional crops of the region need to be encouraged by providing monetary and non-monetary incentives.
3. There is a need to strengthen the groundwater management by imposing restrictions on excessive use of water.
4. The water-saving technologies for conservation of the water resources should be adopted. Efforts should be made to increase water use efficiency through Integrated Watershed Management Programme.
5. To increase public awareness about and active participation in water resource conservation, farmers organizations are required to manage groundwater resources in cooperation with government institutions.
6. Southwestern Haryana has a good canal network. Surface irrigation should be extended to the areas facing problem of groundwater depletion. On the other hand, the areas having problems of waterlogging and water table rise should be provided drainage and pumping of groundwater. There is a need of conjunctive use of water in the study area.

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