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Depleting Groundwater in Haryana: A Temporal Analysis

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Abstract Gorundwater is the largest fresh water resource all over the world. It plays a major role in ensuring livelihood security via use for irrigation, domestic and industrial purposes. The continuously increasing demands for irrigation of rapidly increasing paddy-wheat cultivation area and other purposes has led to excessive drafting of groundwater causing a stage of groundwater depletion in Haryana. The present study has critically analysed the district wise trends of groundwater levels in the state during the study period from June 1974 to June 2015. Thirteen out of 21 districts have been reported to be in the alarming situation regarding stage of groundwater development as either all the blocks of these districts are already over-exploited or in the stage of semi-critical to critical. Mahendragarh district has recorded maximum declining rate (-0.70 m/year) followed by Kurukshetra, Gurgaon and Kaithal. In regard of average negative storage change in the water table, Mahindragarh district again has recorded maximum negative change (-16043.4 ham/year) followed by Kaithal and Kurukshetra. The study reveals that although situation is alarming in most of the districts of the state, four districts (Mahendragarh, Kurukshetra, Kaithal and Gurgaon) are entering in the stage of dry in near future if groundwater use patterns remain same.

Keywords Groundwater depletion, Water table, Storage, Haryana.

Introduction

Groundwater (water occupying all the voids in a geological formation known as aquifer) is a replenishable resource of water constituting major portion of the Earths water circulatory system known as hydrologic cycle. It is the worlds largest fresh water resource and India has emerged as one of the largest users of groundwater throughout the world. Groundwater accounts for Indias 85% of rural domestic water requirements, 50% of urban water requirements and more than 60% of irrigation requirements. Groundwater can provide a reliable stock to farmers during the draught conditions and is considered to be less vulnerable than surface water to climatic changes. The continu-

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Table 1. Availability of groundwater resources in Haryana in bcm. Source: [3, 4].

Year	Annual replenishable groundwater resource	Net annual availability	Annual groundwater draft	Stage of GWD (%)
2004	9.31	8.63	9.45	109
2009	10.48	9.80	12.43	127
2011	10.78	9.79	13.06	133

Table 2. Periodic increase in over-exploited blocks of Haryana. Source: For Row No. 2: [8]; For Row No. 3,4 and 5: [3, 4].

1	Period	Number of blocks
2	1992	24
3	1998	33
4	2004	55
5	2011	71

ously increasing demand of groundwater for irrigation and other purposes has led to the permanent lowering of groundwater levels which is known as groundwater depletion. Although groundwater depletion is a global problem as total global groundwater depletion has increased from 126 km^3 a^{-1} in 1960 to 283 km^3 a^{-1} in 2000 [1], India is among the worst groundwater situation facing countries. A high rate of groundwater depletion (4.0 ± 1.0 cm/year) has been reported in northern region of India (including Rajasthan, Punjab, Haryana and Delhi) by NASA during the period of Auguat 2002 to October 2008. During this period, 109 km^3 of groundwater has lost which is double the capacity of largest reservoir of India, the Upper Wainganga [2].

India is an agriculture based economy and 89% of the extracted groundwater is used in irrigation sector making it the highest category user. Presently, tube wells have become the largest single source of irrigation causing gradual increase in depletion of groundwater resource. Central groundwater board (CGWB) has reported that the stage of groundwater development (GWD) in Haryana has reached to 133 in 2011 from 109 in 2004 with fourth position after Punjab (172), Rajasthan (137) and Delhi (137) in the country [3, 4].

Groundwater levels in Haryana are depleting rapidly due to excessive over-exploitation mainly for irrigation, threatening the future of agricultural productivity. Paddy-wheat cropping area in the state has increased from 935,000 hectares in 1966-67 to 3,603,000 hectares in 2012-13 covering approximately 88% of total cereals area sown. The State Agriculture Department, 2012 revealed that most districts in the state have witnessed critical depletion levels in past 12 years. The following districts namely, Mahendergarh (19.45 m) and Fatehabad (15.79 m) have recorded maximum fall in groundwater levels. Recently, CGWB (2016) has presented the groundwater level scenario in India by analyzing a total of 14974 observation wells. A range of 0.16 to 65.30 meter below ground level (mbgl) depth to water level has been observed in observation wells of Haryana. Two per cent observation wells of the state have reached the level of more than 40 mbgl, 11% wells in deep water levels of 20–40 mbgl and 25% wells in moderately deep water levels of 10–20 mbgl. More than 80% blocks of the state are unsafe (GWD > 70%) regarding goroundwater extraction i.e. these are either in the category of over exploited or in critical and semi-critical stage of development, which are vulnerable to over exploitation [4]. Geographical information system (GIS) technology has been found to be a useful tool for long term assessment of groundwater resources [5]. So, the present study was conducted to study the trends of declining groundwater levels and the temporal patterns of change in groundwater storage in the study area.

Study area

Haryana is the seventeenth state of India located on the north-western heartland of the country. The state is located between 27°39´ to 30°35´ N latitude and

Figure 1

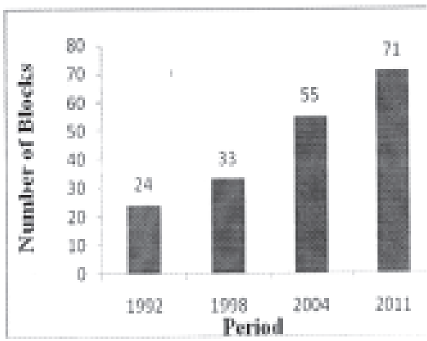

Figure 2

Fig. 1. Location map of study area. **Fig. 2.** Over-exploited blocks of Haryana.

between 74°28´ and 77°36´E longitude. The altitude of Haryana varies between 700 to 3600 ft (200 metres to 1200 metres) above mean sea level and sloping from north to south but slope reverses in south and south-west due to presence of Aravalli hills. The state has 4.42 m ha of geographical area which is divided into four administrative subdivisions having 21 districs, 126 blocks, 154 cities and towns and 6841 villages. Shivalik hills in the north, Yamuna river in the east, Aravalli hills in the south and semi-desert sandy plain in the southwest form the geographical boundaries of the state. Geologically, Haryana is a part of the Indo-Gangetic alluvial plain containing sand, clay, silt and hard calcareous concretions with sand dunes formation in south-western parts making the soil arid and unproductive in this region. Rainfall in Haryana is irregular spatio-temporally with a short rainy sea-son (July to September) followed by a long dry sea-son. Average rainfall of the state was 354.5 mm with a range of 193–1382 mm in 2013. The states economy is mainly based on agriculture as 70% of residents are engaged in agriculture with wheat-paddy cropping pattern occupying more than half of the gross cropped area. Location map of study area is shown in Figure 1.

Materials and Methods

Present study is conducted using secondary data from various sources. District wise levels of ground-water in June 1974 and June 2015 were collected from the Groundwater Cell of Agriculture Department, Haryana. The change in groundwater storage was estimated by following the methodology approved by National Groundwater Estimation Committee [6]. Groundwater storage changes for all the districts were estimated using following formula:

$$\Delta \text{GWS} = \text{Aaq} \times \text{GWT} \times \text{Sy}$$

Where, Δ GWS - change in groundwater storage, Aaq - area of aquifer, GWT - fluctuation in groundwater table, Sy - specific yield.

Different ranges of specific yield have given by GEC for different type of geological formations, how-ever, a uniform value of 0.12 has been used in the present study [7].

From the data of district wise levels of ground-water table in June 1974 and June 2015, rate of ground-water table fluctuation and average changes in groundwater storage were then mapped using Arc GIS software and analysed to study the temporal changes in groundwater storage.

Table 3. District wise categorization of blocks and stage of groundwater development in Haryana (2011). Source: [4].

District	Over exploi- ted	Criti- cal	Semi- critical	Safe	Total	Stage of GWD (%)
	Number of blocks under different categories					
Ambala	3	1	–	2	6	94
Bhiwani	5	–	1	3	9	79
Faridabad	–	2	–	–	2	81
Fatehabad	5	1	–	–	6	179
Gurgaon	4	–	–	–	4	232
Hisar	2	–	1	6	9	91
Jhajjar	–	–	1	4	5	96
Jind	4	1	1	1	7	99
Kaithal	5	–	–	–	5	212
Karnal	6	–	–	–	6	140
Kurukshetra	5	–	–	–	5	217
Mahendragarh	5	–	–	–	5	107
Mewat	1	2	1	1	5	67
Palwal	2	2	–	–	4	105
Panchkula	–	3	–	–	3	85
Panipat	5	–	–	–	5	167
Rewari	4	1	–	–	5	112
Rohtak	–	–	1	4	5	68
Sirsa	7	–	–	–	7	154
Sonepat	3	1	1	2	7	122
Yamunanagar	5	1	–	–	6	135
Total	71	15	7	23	116	133

Table 4. District wise rate of groundwater fluctuation in Haryana. - declining levels, + increasing levels, Source: For Col. No. 1, 2 and 3: [9] and Col. No. 4 and 5 computed by author.

Districts	Depth to water table June, 1974 (m)	June, 2015 (m)	Total fluc- tuation (m)	Rate (m/year)
1	2	3	4	5
Ambala	5.79	11.15	–5.36	–0.13
Bhiwani	21.24	22.59	–1.35	–0.03
Faridabad	6.42	16.37	–9.95	–0.24
Fatehabad	10.48	24.26	–13.78	–0.34
Gurgaon	6.64	26.74	–20.10	–0.49
Hisar	15.47	7.63	+7.84	+0.19
Jhajjar	6.32	3.57	+2.75	+0.07
Jind	11.97	13.44	–1.47	–0.04
Kaithal	6.28	25.03	–18.75	–0.46
Karnal	5.72	18.35	–12.63	–0.31
Kurukshetra	10.21	34.53	–24.32	–0.59
Mahendra- garh	16.11	44.96	–28.85	–0.70
Mewat	5.50	11.04	+5.54	+0.14
Palwal	5.37	9.67	–4.30	–0.10
Panchkula	7.58	17.36	–9.78	–0.24
Panipat	4.56	17.60	–13.04	–0.32
Rewari	11.75	24.63	–12.88	–0.31
Rohtak	6.64	3.80	+2.84	–0.07
Sirsa	17.88	18.94	–1.06	–0.03
Sonepat	4.68	8.36	–3.68	–0.09
Yamunanagar	6.26	12.71	–6.45	–0.16
State Average	9.19	17.75	–8.56	–0.21

Results and Discussion

Groundwater resources of Haryana are depleting at a very fast rate as it is among the most heavily irrigated states of India and 57.5% of irrigation is done through tube wells. Present scenario of groundwater development, rate of fluctuation in water able and periodic changes in groundwater storage has been discussed in the present paper.

Ground water resource and its utilization patterns

As on 31.3.2011, total annual replenishable groundwater resource was 10.78 billion cubic meters (bcm) which is by recharge from rainfall and other sources during monsoon and non-monsoon seasons. The annual groundwater draft was 13.05 bcm, out of which 94.64% was drafted for irrigation and the rest 5.44% was drafted for domestic and industrial uses. During the period of 2004 to 2011, the annual replenishable groundwater resource has increased by 13.61% only, however, gross annual draft has increased by 27.64% enhancing the stage of groundwater development (Table 1). The excess groundwater draft has led to the increase in number of blocks in the category of over-exploitation.

There has been a considerable increase in the extraction of groundwater resource in the last two decades. As evident from Table 2 and Figure 2, the stage of over-exploitation has reached to the critical level in last 20 years. The percentage of over-exploited blocks has increased from 25% in 1992 to 61% in 2011. It suggests that groundwater availability of the state is in very poor condition. If the trends of groundwater extraction remain same, the whole state will be in

Figure 3

Figure 4

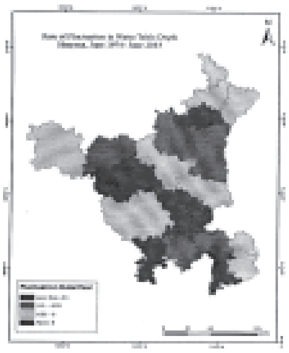

Figure 5

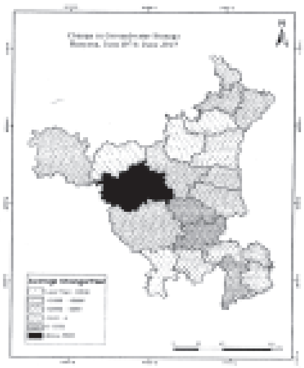

Figure 6

Fig. 3. Depth to water table (June, 1974). **Fig. 4.** Depth to water table (June, 2015). **Fig. 5.** Rate of fluctuation in water table. **Fig. 6.** Average change in groundwater storage.

the stage of over-exploitation in near future.

Out of 116 blocks of Haryana (Morni block was not assessed), 71 are over-exploited (GWD > 100%), 15 are critical (GWD: 90–100%), 7 are semi-critical (GWD: 70–90%) and only 23 blocks are in safe category (GWD: < 70%). In other words, more than 80% blocks are unsafe (GWD: > 70%) in contest of groundwater availability (Table 3). During the period of 2004 to 2011, unsafe blocks have increased from 71 (63%) to 93 (80%) with over-exploited increased from 55 (48.7%) to 71 (61.2%). All blocks of districts Kaithal (5), Karnal (6), Kurukshetra (5), Panipat (5) and Sirsa (7) are over-exploited. This could be due to excessive over drafting of groundwater for irrigation in these districts as a vast cultivable area is sown with Paddy-wheat cropping pattern. Ten out of 11 blocks of districts Gurgaon, Mahendragarh and Rewari are in over-exploited category. This could be due to poor surface water irrigation facilities and low rainfall in these districts. Moreover, the stage of groundwater development has reached to more than 100% in these districts and even more than 200% in three districts (Gurgaon, Kaithal and Kurukshetra) indicating no

Table 5. District wise assessment of changes in groundwater storage in Haryana. Source: For Col. No. 1 and 2 [9] and Col. No. 3 and 4 computed by author.

District 1	Area (Km^2) 2	Δ GWS (ham) 3	Average Δ GWS (ham/year 4
Ambala	1574	-101239.7	-2469.3
Bhiwani	4778	-77403.6	-1887.9
Faridabad	782	-93370.8	-2277.3
Fatehabad	2538	-419683.7	-10236.2
Gurgaon	1215	-293058	-7147.8
Hisar	3983	+374720.6	+9139.5
Jhajjar	1834	+60522	+1476.1
Jind	2703	-47663.3	-1162.5
Kaithal	2317	-521525	-12720.1
Karnal	2520	-381931.2	-9315.4
Kurukshetra	1530	-446515.2	-10890.6
Mahendragarh	1900	-657780	-16043.4
Mewat	1499	+99653.5	+2430.6
Palwal	1367	-70537.2	-1720.4
Panchkula	898	-105389.3	-2570.5
Panipat	1268	-198416.6	-4839.4
Rewari	1594	-246368.6	-6008.9
Rohtak	1745	+59469.6	+1450.5
Sirsa	4277	-54403.4	-1326.9
Sonepat	2122	-93707.5	-2285.5
Yamunanagar	1768	-136843.2	-3337.6

scope for further groundwater extraction. There must be immediate and effective groundwater depletion control strategies to prevent these blocks from the state of Dry and to sustain the agriculture productivity which is backbone of the state.

Depth to water table

The depth to water level data of all the districts of Haryana for a period of approximately four decades (June 1974 – June 2015) was used for computation of total fluctuation in groundwater table and rate of fluctuation was calulated (Table 4).

A range of +7.84 to –28.85 m fluctuation in groundwater table of different districts of Haryana has been observed during these 41 years of the study period. Except 4 districts (Hissar, Mewat, Jhajjar and Rohtak), the whole state is showing declining trends in groundwater levels. Highest rate of depletion in groundwater table has been observed in Mahendragarh district (0.70 m/year) with the total fluctuation of –28.85 m followed by Kurukshetra, Gurgaon and Kaithal. The depth to water table was mapped using GIS for June 1974 (Figure 3) and June 2015 (Figure 4). The rate of fluctuation in water table has been depicted in Figure 5.

Change in groundwater storage

The depth to water level data of all the districts of Haryana for a period of approximately four decades (June 1974 – June 2015) was used for computation of changes in groundwater storage (Table 5).

The highest negative average change in groundwater storage was found in Mahendragarh district (-160043.4 ham/year) followed by Kaithal and Kurukshetra. Lowest negative average change in groundwater storage was reported in Jind (-1162.5 ham/year). Positive average changes in groundwater storage (1450.5 – 9139.5 ham/year) have also been reported in four districts (Hissar, Mewat, Jhajjar and Rohtak). Average change in groundwater storage have been depicted in Figure 6.

The change in groundwater storage is directly related to water table fluctuation, hence, Mahendragarh district has been reported to be suffering from maximum average groundwater storage changes. This could be attributed due to low rainfall and poor canal water irrigation facilities causing extraction of groundwater for sustenance of agriculture and other sectors for water [7—9]. The declining levels of groundwater in kaithal, Kurukshetta, Karnal and other districts may be due to increasing cultivable area with high water consuming Paddy-wheat cropping system causing excessive extraction of groundwater for irrigation purpose [10, 11]. Four districts namely Hissar, Mewat, Jhajjar and Rohtak have shown increasing trends regarding depth of water table and change in groundwater storage, however, recent studies on past one decade data shows that groundwater levels are also declining in some blocks of Mewat [12] and Hissar [13] districts. Secondly, these districts have been reported to be suffering from alinity and other quality related problems in groundwater. So, further studies are required to study the quality related problems in these districts as groundwater is more vulnerable to contamination in such areas where water table in high.

Conclusion

Groundwater resources of the state are depleting rapidly. Present study reveals that 13 out of 21 districts in Haryana are facing critical situation regarding stage of groundwater development as either all the blocks of these districts are already over-exploited or in the stage of semi-critical to critical. Moreover, safe districts regarding quantity of groundwater are facing problems of water quality. In view of the exponentially declining groundwater resources and changing land utilization patterns in the state, there is an emergent need to regulate the excessive extraction of this resource. Ideal groundwater management strategies for further prevention of groundwater depletion by artificial recharging of the aquifers from rain water harvesting, changing landuse pattern from paddy-wheat cropping to less water consuming crops and patricipatory approach in groundwater management must be followed.

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