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Spatio-Temporal Analysis of Groundwater in Bhiwani District, Haryana

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Abstract – Groundwater is the world's largest fresh water resource available for human use on earth. It plays a significant role in providing food security through use for irrigation and domestic purposes. Groundwater resources are rapidly shrinking throughout the world either in the form of quantity or quality or both. India is one of the largest users of this resource as more than 50 percent of irrigation is done through groundwater. The demand of groundwater is continuously increasing in Bhiwani district for the irrigation as well as domestic and industrial purposes. Due to the continuously depleting groundwater in the district, the present study has been conducted to analyse the block wise trends of groundwater levels during the study period from June, 2006 to June, 2016. Three out of nine blocks of Bhiwani district have observed depletion in groundwater levels. Heavy groundwater drafting has been reported in Badhra and Loharu blocks as depth to water table has increased at a rate of 2.65 and 1.75 meter/year respectively during the study period. However, depth to water table has shown slight positive changes in other six blocks. Maximum decline in groundwater storage has occurred in Loharu block (16622.49 ham/year) followed by Badhra (14219.96 ham/year) indicating excessive groundwater drafting. The present study shows that the two blocks (Loharu and Badhra) of the district are in critical situation of groundwater levels and recommends immediate action for the control and management of continuously depleting levels of groundwater in these blocks.

Keywords: Bhiwani, Groundwater, Rate and Magnitude of Depletion, Spatial and Temporal Analysis.

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INTRODUCTION

Water, a unique renewable resource on earth, is essential for sustenance of all forms of life, food production and economic development. Both the surface water and groundwater play a major role in daily requirements of water, however, due to rapid urbanisation, population growth, global warming and deterioration in quality of surface water, the dependence on groundwater has increased. In the last few decades groundwater has been drafted with a high rate throughout the world. This over-drafting or over-exploitation of groundwater resources for the increasing demands of irrigation, domestic and industrial purposes has led to the permanent lowering in the levels of groundwater which is known as groundwater depletion.

A remarkable change has been observed in groundwater scenario throughout India in the last few decades. The use of groundwater for irrigation purpose has tremendously increased in country after green revolution. The area under groundwater irrigation has increased by 105% between 1970 and 1994, whereas, the area under surface water irrigation has increased only by 28% (Shah, 2002). NASA has reported that from August 2002 to October 2008, 109 km^3 of groundwater has been drafted in the northern region of India (Rajasthan, Punjab, Haryana and Delhi) with a rate of 4.0 ± 1.0 cm/year (Rodell et al., 2009). Levels of groundwater in Haryana are also deepening sharply. The stage of groundwater depletion has reached from 109 in 2004 to 133% in 2011. According to Central groundwater board (CGWB, 2011) 71 out of 116 blocks of the state including 5 blocks of Bhiwani district are over-exploited where stage of groundwater development is more than 100%. Groundwater levels in Bhiwani district have been depleted with a rate of 0.03 meter/year in the last four decades (Kharb, 2017). Geographical information system (GIS) technique has been widely used as an important tool for groundwater depletion assessments all over the world. So, the present study has been conducted to assess the changing scenario of groundwater levels, their rate and magnitude in different blocks of Bhiwani district by applying GIS techniques.

STUDY AREA

Bhiwani (created on 22 December 1972) is eighth district situated between 28º 19´ & 29º 05´ N latitude and 75º 26´ & 76º 28´ E longitude in south-western part of Haryana. It was the largest district of state by

area before the creation of Charkhi Dadri as 22nd district (on 4 December 2016; however study was conducted before the creation of new district). Bhiwani district has 5140 km^2 geographical area with 4 divisions, 5 tehsils and 444 villages. The district is a landlocked area surrounded by Hisar in North, Rohtak in North-east, Jhajjar in East, Mahendragarh & Rewari in South and Rajasthan state in South-west. Geologically, Bhiwani district has flat plains with clusters of sand dunes in western parts and rocky ridges. The district has very less natural flowing water and Dohan river is the only stream in this region which ultimately dies in sands. Climate of the district is classified as tropical steppe, semi-arid and hot. The normal annual rainfall in the district is 420 mm which is unevenly distributed over the area and occurs mainly in monsoon season (July-September). Location map of study area is shown in figure 1.

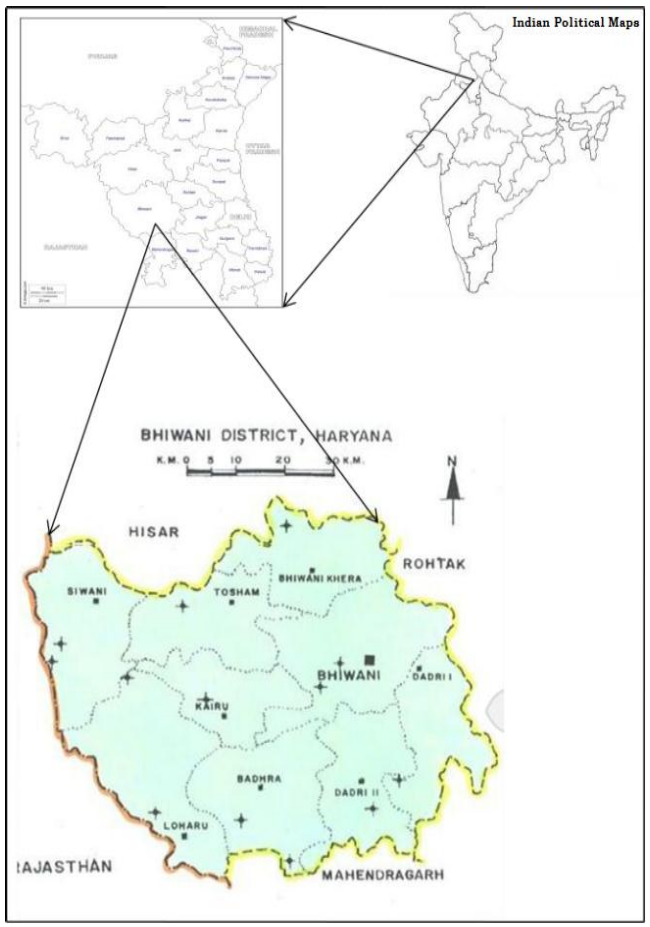

Figure 1 Location map of study area

MATERIALS AND METHODOLOGY

The present study has been conducted for the block wise assessment of depleting groundwater levels in Bhiwani district by using secondary data from Groundwater cell, Bhiwani for the period of June 2006 to June 2016.

Estimation of groundwater changes

The groundwater storage changes were estimated by applying the methodology approved by National Groundwater Estimation Committee (GEC, 1997). Groundwater storage changes for all the blocks were estimated using following formula:

Δ GWS = Aaq x GWT x 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, however, a uniform value of 0.12 has been used in the present study (Singh and Jeet, 2016).

Magnitude of the groundwater depletion for each block has been calculated using the following equation:

Magnitude of depletion (m3/day) = ΔGWS (ham) x 10000/365

Mapping for temporal analysis of depleting levels of groundwater in different blocks of the district was done using *ArcGIS*-version10.

RESULTS AND DISCUSSION

The levels of groundwater are tremendously depleting in Haryana state as more than 50% irrigation in the state is done through tube wells and the Bhiwani district is also not lagging behind in groundwater extraction. In the present paper, the rates of fluctuation and changes in groundwater storage of different blocks have been estimated to predict the current situation of groundwater in the district.

Temporal analysis of groundwater

Water table depth

The block wise depth to water table data of all the nine blocks of Bhiwani district has been used for estimation of total fluctuation in groundwater during the period from June 2006 to June 2016 and rate of groundwater fluctuation was calculated for each block (table 1).

Table 1 Block wise rate of groundwater fluctuation in Bhiwani district

Block	Depth to water table (meter)		Total fluctuation (meter)	Rate of fluctuation (m/year)
	2006	2016		
1	2	3	4	5
Badhra	38.37	64.88	-26.51	-2.65
Bawani khera	6.15	5.67	0.48	0.05
Bhiwani	6.00	4.91	1.09	0.11
Dadri-I	7.08	6.43	0.65	0.07
Dadri-II	8.12	8.60	-0.48	-0.05
Kairu	17.68	16.41	1.27	0.13
Loharu	41.90	59.39	-17.49	-1.75
Siwani	28.66	21.31	7.35	0.74
Tosham	11.53	10.82	0.71	0.07
Source: Col. No. 1, 2 and 3 from Groundwater cell, Bhiwani; Col. No. 4 and 5 computed by authors				

A range of + 7.35 to -26.51 m fluctuation in water table has been observed in blocks of Bhiwani district during the analysis period of last 10 years. Badhra block has reported maximum decline in water table with highest fluctuation rate of -2.65 m followed by Loharu block (-1.75 m). Dadri-II block has also shown slow depletion of groundwater, however, six blocks (Bawani khera, Bhiwani, Dadri-I, Kairu, Siwani and Tosham) have shown positive changes in groundwater fluctuation i.e. levels of groundwater have risen up in these blocks. The water table depths were mapped for June 2006 (figure 2) and June 2016 (figure 3). Rate of groundwater fluctuation has been presented in figure 4.

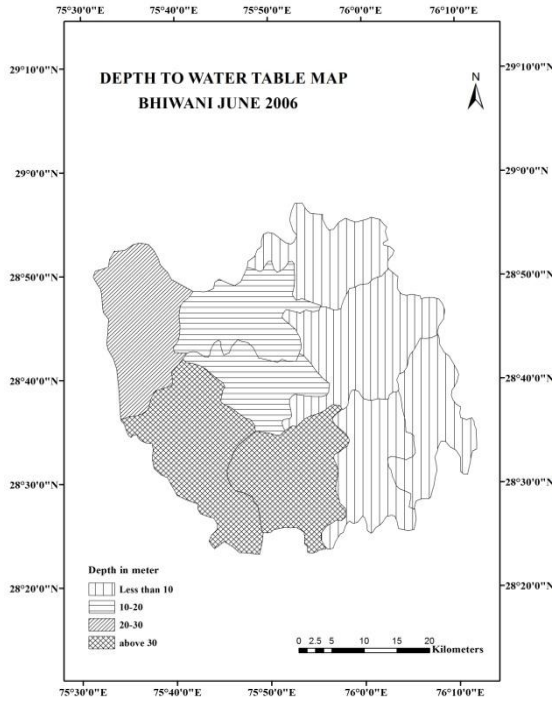

Figure 2 Block wise depth to water table in June 2006

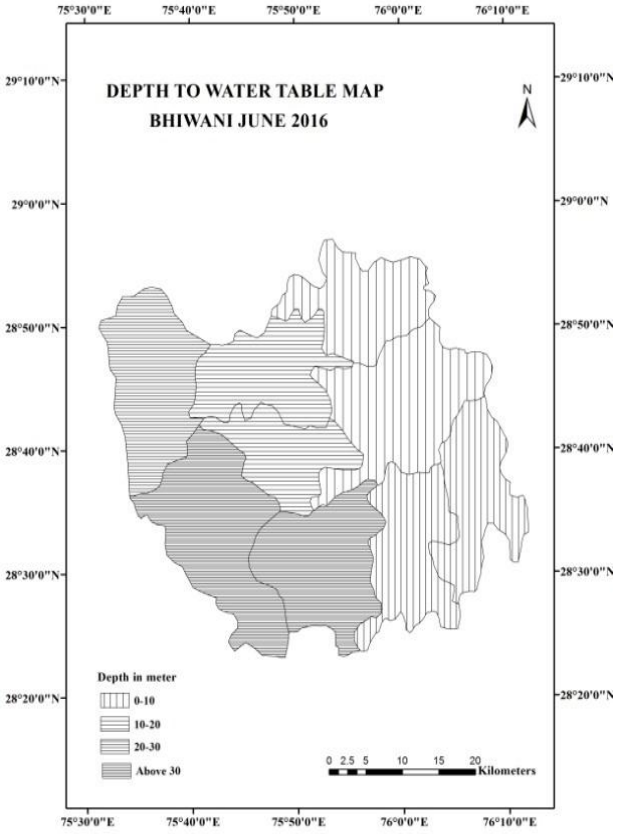

Figure 3 Block wise depth to water table in June 2016

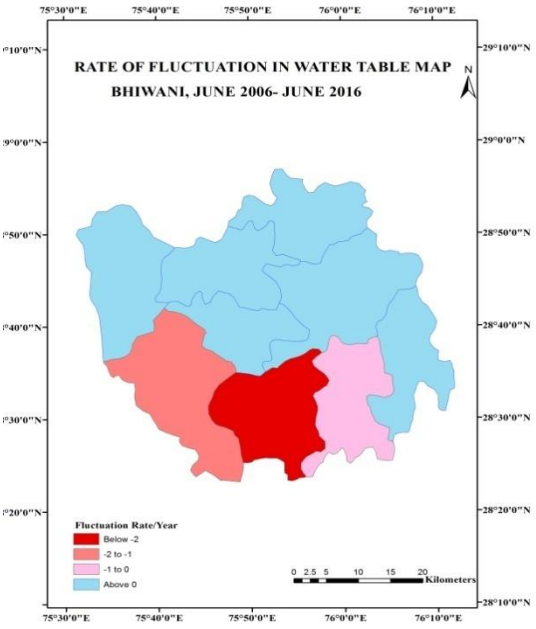

Figure 4 Block wise water table fluctuation rate

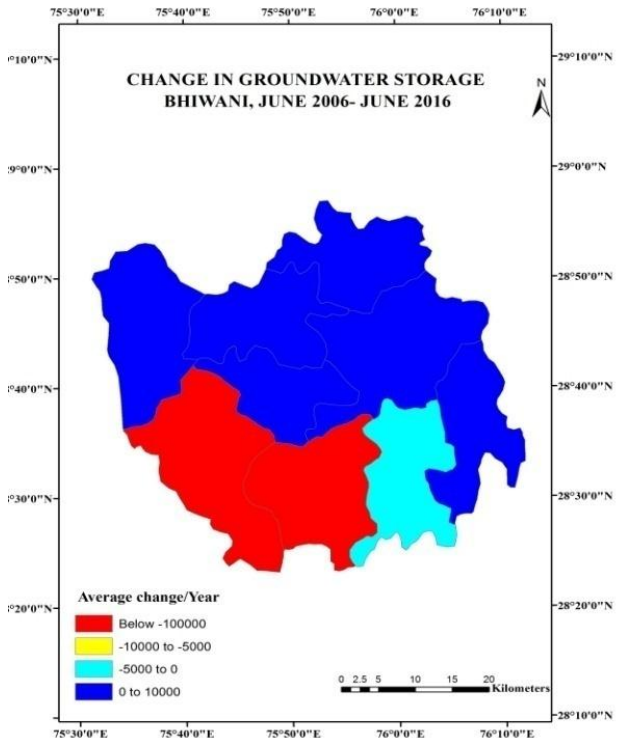

Figure 5 Block wise average change in groundwater storage

CHANGES IN GROUNDWATER STORAGE

The depth to water table and geographical area data of each block of the district from June 2006 to June 2016 taken from Groundwater cell, Bhiwani was used for the computation and analysis of changes in groundwater storage (table 2). Maximum decrease in average groundwater storage has been found in Loharu block (-16622.49 ham/year) followed by Badhra (-14219.96 ham/year) and Dadri-II blocks (-297.79 ham/year). Average groundwater storage has increased in six blocks with values ranging from 287.82 (Bawani khera block) to 6156.36 ham/year (Siwani block). The average changes in storage of groundwater are shown in figure 5.

Table 2 Block wise assessment of changes in groundwater storage in Bhiwani district

Block	Area (km2)	ΔGWS (ham)	Average ΔGWS (ham/year)	Magnitude of depletion (m^3/day)
1	2	3	4	5
Badhra	447	-142199.64	-14219.96	-389588.06
Bawani khera	557	3208.32	320.83	8789.04
Bhiwani	685	8959.80	895.98	24547.39
Dadri-I	369	2878.20	287.82	7884.93
Dadri-II	517	-2977.92	-297.79	-8158.68
Kairu	419	6385.56	638.55	17494.68
Loharu	792	-166224.96	-16622.49	-455410.85
Siwani	698	61563.60	6156.36	168667.39
Tosham	387	3297.24	329.72	9033.53

Source: Col. No. 1 and 2 from Groundwater cell, Bhiwani; Col. No. 3, 4 and 5 computed by authors

MAGNITUDE OF GROUNDWATER DEPLETION

The problem of groundwater depletion can be properly assessed by quantifying the magnitude of its depletion within specific time period. Block wise magnitude of groundwater depletion has been calculated and analysed (table 2). Maximum magnitude of groundwater depletion (-455410.85 m^3/day) has been observed in Loharu block followed by Badhra block (-389588.06 m^3/day). A low magnitude of depletion has also been reported in Dadri-II block (-8158.68 m^3/day). Rest all the six blocks have shown a magnitude of groundwater recharge ranging from 7884.93 to 168667.39 m^3/day indicating some rising levels in water table as well groundwater stores for future use. The decreasing average groundwater storages and high magnitude of groundwater depletion in Loharu and Badhra blocks might be because of excessive drafting for irrigation purposes, less recharge and low rainfall in these areas. Kumar et al. (2015) has also reported depleting quantity as well as quality of groundwater in Loharu block (Bhiwani district) where depth to water table has been observed between 60-70m.

SPATIAL ANALYSIS OF GROUNDWATER

The block wise levels of groundwater in Bhiwani district were assessed from the data of June 2016. The ranges of water table depth in different blocks were categorised into various categories as 0-3, 3-10, 10-20, 20-30, 30-40 and more than 40m. The areas of each block having range of depth to water table are shown in table 3. The percent areas of different blocks falling in different categories of groundwater levels have been depicted as bar graphs in figure 2.

Table 3 Block wise ranges of water table depths in Bhiwani district, June 2016

Block	Area (Ha)	Depth to water table (in m)					
		0-3.0	3.0-10	10-20	20-30	30-40	>40
Badhra	44067	- (0)	-(0)	289 (0.65)	825 (1.85)	3154 (7.06)	39001 (87.32)
Bawani khera	55732	5876 (10.54)	44781 (80.35)	5075 (9.11)	- (0)	-(0)	-(0)
Bhiwani	68474	16482 (24.07)	46784 (68.32)	663 (0.97)	1040 (1.52)	2628 (3.84)	870 (1.27)
Dadri-I	36887	15508 (42.04)	17167 (46.54)	3536 (9.59)	413 (1.12)	140 (0.38)	-(0)
Dadri-II	51656	5221 (10.11)	18192 (35.22)	21491 (41.6)	1396 (2.7)	882 (1.7)	2371 (4.58)
Kairu	41858	-(0)	3168 (7.57)	23658 (56.52)	7267 (17.36)	4684 (11.19)	3081 (7.36)
Loharu	79232	- (0)	-(0)	-(0)	1268 (1.6)	4851 (6.12)	73113 (92.28)
Siwani	69853	-(0)	6804 (9.74)	34067 (48.77)	20416 (29.23)	4485 (6.42)	4081 (5.84)
Tosham	38713	1025 (2.65)	14153 (36.56)	21768 (56.23)	735	-(0)	-(0)

Source: Groundwater cell, Bhiwani; values in parentheses are percent values and computed by author

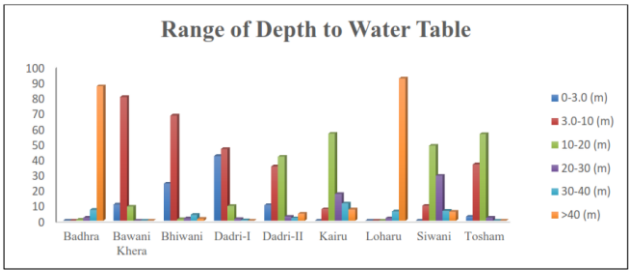

Figure 2

Table 3 and figure 2 shows that groundwater situation in Badhra and Loharu blocks is in extreme scarcity conditions as 87.32 and 92.28% area of the respective blocks falls in category more than 40 m of water table depth. Dadri II, Kairu, Siwani and Tosham blocks are in scarcity condition of water table depths as more than 50.58, 92.43, 90.26 and 58.13% areas of the respective blocks have groundwater below 10m depth. The levels of water table were satisfactory only in three blocks i.e. Bawani Khera, Bhiwani and Dadri I [here for better understanding the blocks, according to water table depth, have been divided into extreme scarcity (more than 40m), scarcity (more than 10m) and satisfactory (less than 10m) categories]. The present scenario of groundwater levels is in alarming stage and the levels will go deepening if the efficient groundwater recharge and draft policies have not been implemented in the district.

CONCLUSION

The depleting levels of groundwater in Loharu and Badhra blocks have reached to the alarming situation of groundwater for irrigation as well as domestic and other purposes and if the groundwater extraction continues with this rate, these two blocks will be dry off of groundwater. The levels of groundwater are also depleting rapidly in Dadri II, Kairu, Siwani and Tosham blocks. So, there is an immediate need of action to control the drafting of groundwater, shifting from high water consuming to less water consuming crops, strict rules on digging of tube wells and artificial recharge policies of the groundwater in the district.

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