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Spatial variations in groundwater level and fluctuations in Hisar District of Haryana, India

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Abstract
Ground water is often developed without proper understanding of its occurrence in time and space and its continuous withdrawal over-exploitation and contamination. Water level fluctuations of the observation wells between decades over an area indicate the net changes in the ground water regime and it is an important parameter for planning sustainable ground water development. The present study was conducted at Dept. of Agro- Meteorology to find status of Ground Water in Hisar district for two decades i.e. from 1996-2017. The groundwater data were analyzed for their long - term pattern, and were interpreted graphically to understand the dynamics of the groundwater level and fluctuation. The main objective of this study was to investigate the temporal trends in annual and seasonal groundwater level and fluctuation in Hisar District. The spatial variation of Ground Water was analyzed using Arc GIS software by compilation of existing data, generation of GIS database (shape files), interpolation, categorization, mapping and interpretation. During the pre-monsoon season the groundwater level varied from 2 meters to 12 meters in depth and during the monsoon season it was found from 2 meter to 10 meters below ground level (bgl) during 2017. Noticeable spatial variations were observed in average Ground water level of pre-monsoon & monsoon in the Narnaud and Agroha blocks. The maximum rise in the water level was observed at Agroha Block whereas maximum decline was at Adampur Block.

Keywords: groundwater, fluctuation, pre-monsoon and monsoon, GIS

Introduction
Groundwater is a long-lasting source of water supply for human beings. It is estimated that approximately one third of the world's population use groundwater for drinking purpose (United Nations Environment Program 1999). Overexploitations of natural resources, increased human activities and interventions in natural cycles are putting the groundwater resources at risk. Presence of more than 200 chemical constituents in ground water has been documented including about 150 organic and 50 inorganic and radio nucleotides. The reported sources of these chemicals in ground water are both natural as well as anthropogenic (Office of the Technology Assessment 1984). Contaminants in groundwater aquifers exist for long may be centuries due to their slow movement in water aquifers. Due to variations in the regional geology and water/rock interactions, higher concentrations of many elements can occur in water aquifers. Mostly groundwater exploitation schemes in developing countries are usually designed without due attention to quality issues, which can invite threat to natural environment.
Oscillatory water-level fluctuations are reversible changes in water levels around a long-term mean. During the twentieth century, groundwater abstraction across the world increased explosively. Ground water is often developed without proper understanding of its occurrence in time and space and is, therefore, threatened by over-exploitation and contamination. The Geographical variations indicate the stress condition of the groundwater. It differs not only from country to country, but also shows pronounced spatial variation within countries. Analysis of water table fluctuations (WTF) is a useful tool for determining the magnitude of both short- and long-term changes in groundwater recharge and has been widely applied under varying climatic conditions (Gerhart, 1986; Hall and Risser, 1993; Healy and Cook, 2002, Groundwater Scenario in India, January 2014) [4, 5, 6, 3].
Groundwater level indicates the variability in water level in region with respect to time, space and season. In Monsoon season, the ground water level rise due to increase in storage. Central Ground Water Board (CGWB) analyzed the condition of groundwater, 66% wells shows rise and 31% a fall in water level, of 0-2 m in most cases in India. The decadal water level fluctuation shows that the maximum fall is observed in Punjab, Rajasthan and Tamil Nadu (Groundwater Scenario in India, January 2014) [3].
Ground Water is an important source of the irrigation in Haryana.The Hisar district in Haryana state of India has agriculture based economy. Hence, availability of groundwater in good quantity is of utmost importance for the area. Because of natural physiographic, high population density, and intense agricultural activity, the groundwater levels and quality in the district is under overexploitation. Therefore, the present study was undertaken with an objective to analyse the long term changes in ground water depth and ground water fluctuation with regards to natural conditions prevailing in the area.

Hisar is the western district of Haryana State with a total geographical area of 3860 sq. km and it lies between the North latitudes 28^0 56' to 29^0 38'N and East longitudes 75^0 21' to 76^0 18'E. Hisar city serves as the district headquarters. The district is under control of Hisar division and administratively divided into nine community development blocks namely Agroha, Adampur, Barwala, Bass (Hansi-II), Hansi-I, Hisar-I, Hisar-II, Narnaund, and UklanaMandi. The district is located in the arid zone of the State. Rainfall is scanty and unreliable. The climate of Hisar owes to its continental location on the outer margins of the south-west (SW) monsoon region. It has tropical monsoonal climate and is characterized as arid type of climate. The district has characteristically four seasons during the year *viz*., summer (March to May), SW Monsoon (June to September), Post-Monsoon (October to November) and winter (December to February) season. SW monsoon also known as summer monsoon brings rain during last week of June to mid-September. The main characteristics of climate in the district are its dryness, extremes of temperature and scanty rainfall. The sub soil water is deep and unfit for irrigation in most parts of the district. This uncertainty of rainfall necessitated the development of irrigation through artificial sources of irrigation like canals and tube-wells. The area is irrigated by shallow tube wells and network of Bhakra Canal Systems and Western Yamuna Canal Systems (Aquifer mapping and management plan, 2017). The district area falls in Yamuna sub-basin of Ganga basin. There is no natural drainage in the district area. Canals are irrigating about 76.83 % of the area and 23.17 % (about 63000 ha) is irrigated by ground water (Ground Water Information Booklet, 2013). The major crops in the district are wheat, mustard for rabbi season whereas cotton, paddy in kharif season.

Materials and Methods

The study used secondary sources information. Major sources of data were ground water year published by Central Ground Water Board and Ground Water Cell, Agricultural Department, Government of Haryana and statistical abstract of Haryana as well as central ground water board websites. Boundary map of Hisar district was demarcated in GIS environment using Arc GIS software with the help of Haryana base map. Locations of observation stations (wells) were digitized to prepare point shape file. The study was carried out for period of last 2 decades (1996-2017). Nine stations/ground water observations well were selected representing each block in the Hisar district. The selected observation wells were Kirtan, Dhansu, Chawdhriwas, Kothkalan, Nahla, Samani, Rajli cross, Dhamundicross-2 and Chanut falling in Adampur, Hisar, Narnaud, Ukalana, Agroha, Barwala, Bass and Hansi, blocks respectively. The major activities involved in this process include compilation of existing data, generation of GIS database (shape files), interpolation, categorization, mapping and interpretation.

Result and Discussion

Results of the study are self-explanatory form various maps prepared in the study. For better understanding the interpretation was carried out for long period average groundwater level for seasons (pre monsoon and monsoon), current groundwater level *i.e*. in 2017 and fluctuation of current groundwater level from its long period average.

Ground Water Status in Pre-Monsoon Period

1. Long Period Average Ground Water Level during Pre-Monsoon Period

The long term pre-monsoon data was analyzed by averaging the last 2 decades (1996-2017) water level data. During pre-monsoon ground water level in the district was ranging from 2 to 10 meters bgl (Fig. 1). Water table at Bass (Dhamunicross-2), Hansi (Chanute) and Barwala (Rajali cross) was higher as compared to other parts of district. Eastern parts of district had higher Groundwater level form Western parts.

2. Ground Water Level in Pre-Monsoon 2017

During Pre-monsoon 2017 the ground water level was found form 2 m to 12 m bgl in the district (Fig. 2). In the West and North-East, ground water level was at 12 m bgl at Kirtan and Kothkalan station. Whereas, in southeastern parts it was about 2 m bgl around Dhamundicross-2, Rajli cross and Dhansu stations of Bass, Barwala and Hisar blocks respectively.

3. Fluctuation in Ground Water in Pre-Monsoon 2017 with Respect to Its Long Period Average Level

Ground water fluctuation in pre monsoon period was found between -5 to 2 m. District observed mix pattern of rising as well as declining trends of ground water level of pre monsoon 2017 form its long time average (1996-2017). Rise in water level was found in central parts and decline was in eastern parts. The spatial extent of ground water rise & fall level shown in map (Fig. 3).

Ground water status in Monsoon Period

1. Long Period Average Ground Water Level During Monsoon Period

During monsoon period, average ground water level in the district remained 2-10 meters below ground. Minimum depth of Ground water was about 2 m around Bass block (Dhamundicross-2 station) in southern parts of Hisar district. In the western parts, ground water level was very low and depth was more than 10 m bgl in some parts. Overall, the Monsoon period ground water level in Hisar district was found very low (Fig. 4).

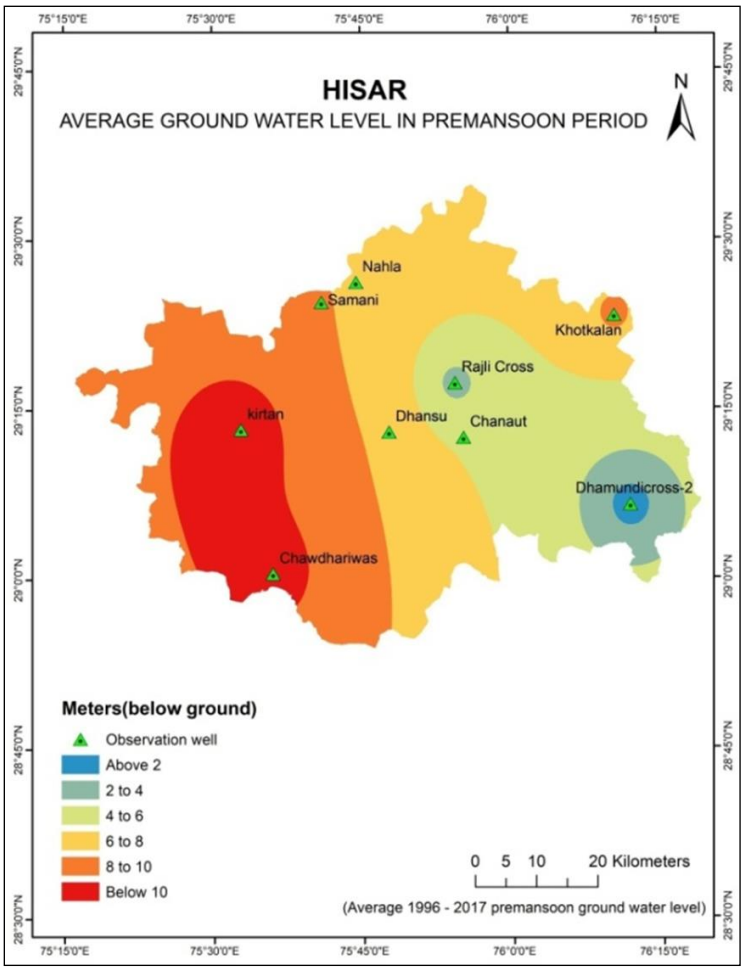

Fig 1: Average ground water levels during pre-monsoon period GW level

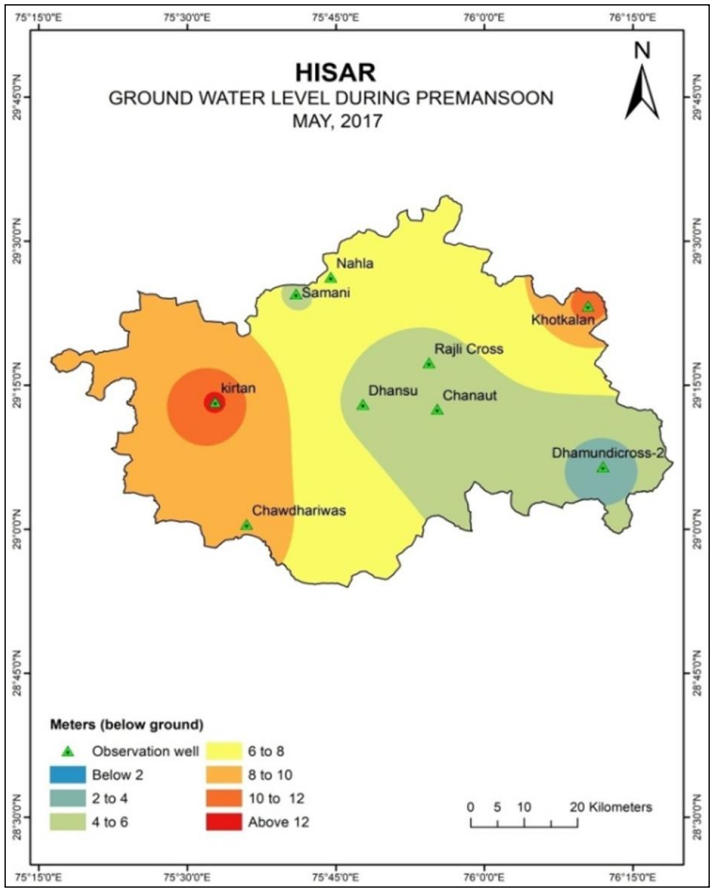

Fig 2: Ground water levels during pre-monsoon 2017(1996-2017)

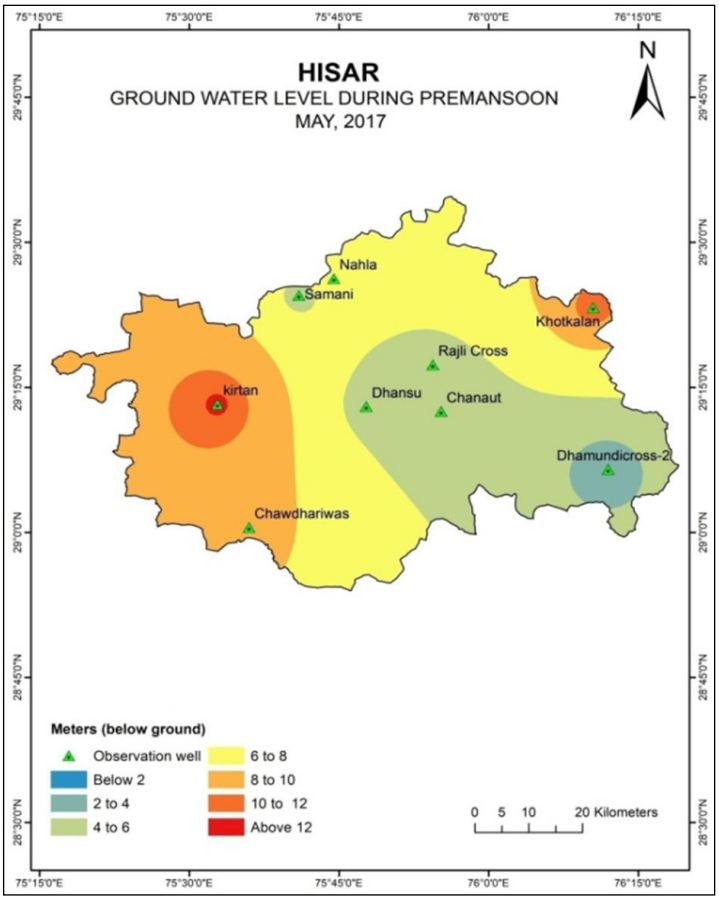

Fig 3: fluctuations in GW level in Pre-monsoon period 2017 from average

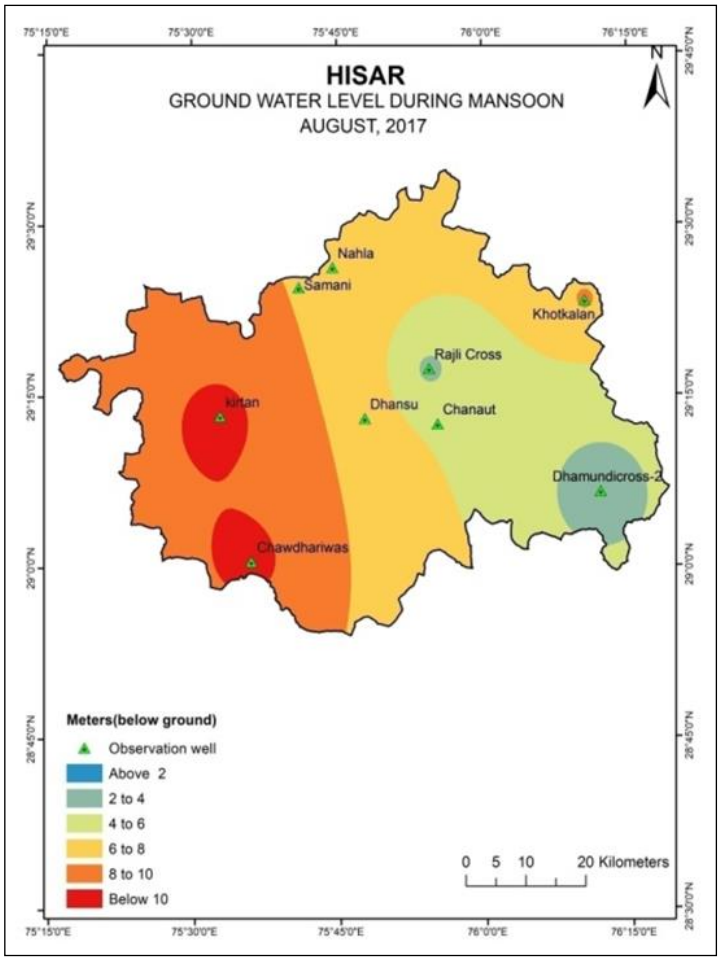

Fig 4: Average ground water levels during Monsoon period GW level (1996-2017)

Table 1: Groundwater level and fluctuation in different stations at Hisar district.

Station	Block	Ground Water Level in Pre-monsoon 2017 (bgl meters)	Ground Water Level in Monsoon 2017 (bgl meters)	Long period Average Ground Water Pre-monsoon 1996-2017 (bgl meters)	Long period Average Ground Water Monsoon 1996-2017 (bgl meters)	Ground water level change/fluctuation during pre-monsoon (5-3)	Ground water level change/fluctuation during monsoon (6-4)
1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Kirtan	Adampur	12.97	13.00	11.48	11.6	-1.49	-1.4
Dhansu	Hisar - I	04.76	03.81	07.14	07.04	02.38	03.23
Chawdhariwas	Hisar - II	09.30	09.03	11.36	10.72	02.06	01.69
Khotkalan	Narnaud	11.67	12.83	08.30	07.79	-3.37	-5.04
Nahla	Uklana	07.45	05.73	07.46	06.16	0.01	0.43
Samani	Agroha	05.06	03.99	07.85	07.43	2.79	03.44
Rajli Cross	Barwala	04.79	04.79	03.28	02.62	-1.51	-2.17
Dhamundicross-2	Bass	01.35	01.29	0.94	01.65	-0.41	00.36
Chanaut	Hansi	03.83	06.52	05.63	05.89	01.8	-0.63

Observation well data in Hisar District (Ground Water Data from CGW

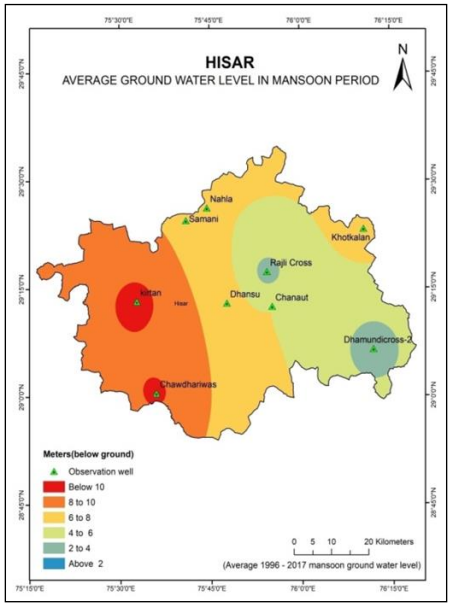

Fig 5: Ground water levels during monsoon 2017

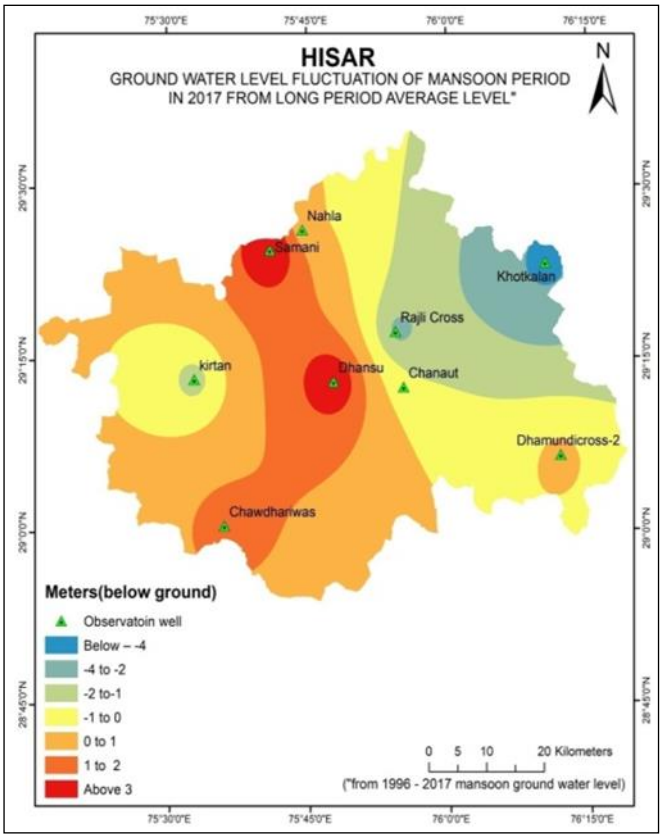

Fig 6: fluctuations in GW level in Monsoon period 2017 from average

2. Ground Water Level in Monsoon 2017

In monsoon season i.e. in August, highest ground water level was found at Dhamundicross-2 station at 2 m bgl. In Kirtan and Chawdhariwas ground water level was 10 m bgl. In the most of Hisar district, ground water level was found very low ranging from 2 to 10 meters or more. South Eastern parts of district had slightly higher water level as compared to Western parts (Fig 5).

3. Fluctuation Ground Water in Monsoon 2017 with Respect to Its Long Period Average of Last 2 Decades

Fluctuation of current year water level *i.e.* 2017 was compared with long period average water level in monsoon period for better estimation of fluctuation. Fig. 6 reveals that a small area observed rise in water table from its normal level. Eastern parts of Hisar district observed rising water table up to 4 meters bgl. Central parts of district had declining water level of up to 3 meters from normal.

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