GIS Based Spatio-temporal Mapping of Groundwater Depth in Hisar District, Haryana State, India

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Publication Date: 21 December 2016

DOI: https://doi.org/10.23953/cloud.ijarsg.75

Abstract Water Resource management is very important for sustained use of natural resources and is vital for existence of mankind. Groundwater plays a significant role due to its easy availability and low cost inputs for use. The present study deals with the monitoring of spatio-temporal changes in groundwater depth in Hisar district of Haryana state, India. A total of 92 observation wells were selected throughout the district for point observations. The groundwater depth (m, bgl) data from 1990 to 2014 of pre-monsoon for each year have been used in the present study. Change detection maps were generated using Inverse Distance Weighted (IDW) interpolation technique in Arc GIS. Depth to water level data at 4 year interval has been considered for monitoring the changes. Long-term variations have also been monitored by using data of 1990-2014 so as to understand the changing groundwater regime in the area. The study revealed uprising trend in average groundwater depth from 12.9 m bgl in 1990 to 8.10 m bgl in year 2014. The changes in the groundwater depth were more prominent in South (rising trend), East (rising trend) and North-east (rising trend) parts of the District. The probable reason for this trend is poor groundwater quality in southern and north-eastern parts of the district hampering the farmers from its use.

Keywords Groundwater Fluctuation; Hisar; Spatial Distribution; GIS; India

1. Introduction

Groundwater has an important role in the environment: it replenishes streams, rivers, and wetlands and helps to support wildlife habitat; it is used as primary source of drinking water and also in agricultural and industrial activities. Around the world, groundwater resources are under increasing pressure caused by the intensification of human activities and other factors such as climate changes. Groundwater is a significant part of the hydrologic cycle, containing 21 percent of Earth's freshwater. Groundwater comprises 97 percent of fresh water not tied up as ice and snow in polar ice sheets, glaciers, and snowfields. This greatly exceeds the amount of water in streams, rivers, and lakes.

Excessive pumping of water from an aquifer may result in an area wide lowering of the water table (Babu et al., 2011). This will eventually occur any place where more water is pumped than is recharged by infiltrating precipitation. Over drafting from an aquifer may result in changes in groundwater quality, a reduction in groundwater availability (and hence the loss of water supply to current and future wells), and perhaps even a permanent loss of the aquifer's capacity to store water.
Many states in India use the water right process to manage groundwater quantity and to ensure that over drafting does not occur. Groundwater is the major source of drinking water in rural India. It is estimated that approximately one third of world’s population use groundwater for drinking purpose. In addition to rural households, public water supplies in various parts of the world depend on wells and groundwater.

Water level fluctuations can result from a wide variety of hydrologic phenomena, some natural and some induced by man (Bagher and Rasoul, 2010). Good management practices demand adequate information on how this volume varies with time. The amount of groundwater in storage is obtained by periodic measurements of the depth to water level from some reference point and keeping track of these measurements over time. Rising water levels in the well means that more water is in storage and vice versa. Chaudhary (2003) explained the importance of groundwater depth data in overall planning and development and emphasized it as an integral component for resource planning.

1.1. Geo-Identity

The Hisar district is situated between 28°05'45” to 29°49’15” N latitudes and 75°13’15” to 76°18’15” E longitudes. The district covers an area of 4174 sq km and is bordered on the east by Rohtak district, on the west by Fatehabad district & Rajasthan state, on the south by Bhiwani district and on the north by Jind district. The location map of the study area is shown in Figure 1. The area is nearly level, with imperceptible slopes, except for the regions in and around the sand dunes locally known as tibbas. The general trend of gradient of the terrain is from north–east to south–west and then west (Haryana district Gazetteer, Hisar). Hisar district comprises of three major physiographic units i.e. Aeolian plain, Older alluvial plain and Chautang flood plain. Major physiographic sub-units occurring in the district are sand dunes, plains, old channels and basin. The west and south-west parts of district are affected by Aeolian activity, comprising of sand dunes, sandy plains and interdunal areas.

The district is a part of the Indo-Gangetic alluvial plain. The Indo-Gangetic alluvium owes its origin to a sag in the crust, formed contemporaneously with the uplift of the Himalayas. This depression has since been filled up by sediments derived from the rivers and channels of northern Himalayas and southern Aravali hills from Pleistocene to recent times. The sub-surface geology of the area has been a subject of speculation for a long time, as the alluvium effectively conceals the solid geology of the floor. The whole of the alluvial plain, with relict channel beds within which the Saraswati, Drishdawati and Ghaggar rivers have occasionally shifted their beds in Holocene times, are covered by Aeolian deposits in the recent past with increasing aridity. Some of the great rivers of fluvial age such as Saraswati and Drishdawati (Chautang) have receded leaving inter-locked alluvial fans along its receding course, which were later covered with Aeolian deposits, and resulted into present landscape scenery within varying monotonous plain having relict channel courses, levees, bars, depressions and sand dunes. The depth of the alluvium varies from 100 meters to more than 400 meters as observed from many geophysical and borehole data (Haryana district Gazetteer, Hisar).

2. Objectives of Study

The present study has been undertaken with the aim to understand the spatial distribution of depth to water table in the area from the year 1990 to 2014. The objectives are briefly enumerated as:

1) To understand the spatial distribution pattern of groundwater level since 1990 to 2014.
2) To understand the pattern of groundwater level fluctuations in the period of 1990-2014.
3. Materials

In present study, Survey of India Toposheet (1:50,000), well observation point data of groundwater level from the year 1990-2014 and other ancillary data in the form of published literature, reports and maps by different organizations involved in groundwater studies have been used. The observation point data has been collected from Groundwater Cell, Department of Agriculture, Govt. of Haryana.

4. Methodology

Base map of the study area was prepared using survey of India topographical maps. The well observation data was plotted on to the map by using location (latitude & longitude) of each well.
In total 92 observation wells were selected for further processing of the data for spatio-temporal analysis. These maps were prepared with the help of IDW spatial interpolation technique in Arc GIS Software (Srivastava et al., 2012) and interpreted using standard methods (Haryana Groundwater Cell, 2014). In this study, IDW technique was used for spatial distribution of Groundwater level fluctuation (m bgl) for pre-monsoon (June) on five year interval (1990-94, 1994-98, 1998-2002, 2002-2006, 2006-2010, 2010-2014) and long term fluctuation (1990-2014). Different interpolation techniques like Krigging, Spline and Inverse Distance Weightage (IDW) were used but IDW was found to be best both in terms of spatial distribution representation and also from accuracy point of view. Inverse Distance Weighted (IDW) is a method of interpolation that estimates cell values by averaging the values of sample data points in the neighborhood of each processing cell. The closer a point to the center of the cell being estimated, the more influence, or weight; it has in the averaging process. Compared with regression analysis ($R^2 = 0.82$), IDW technique is giving more accurate results as compared to other techniques tried for interpolation purpose. The premonsoon data of groundwater depth levels have been used in the analysis as this is the true representation without predominant influence of seasonal recharges due to rains.

Figure 2: Methodology Chart for Analysis of Depth to water level data

5. Results and Discussion

The average value of depth to water level (m bgl) for different blocks for the year 1990, 1994, 1998, 2002, 2006, 2010 and 2014 is shown in Figure 3. The spatial distribution maps of the year 1990, 1994, 1998, 2002, 2006, 2010 and 2014 are shown in Figure 4 (a) and (b). Detailed comparison of these maps indicates that a lot of area which was in the range of 10-20 meter has come in to 3-10 meter which shows a general incline trend of groundwater in the area. The entire area in this category is wide across the district and has a particular pattern/trend along north-east to south-west in 1990.
A close look on the 1994 data shows that the area covered in depth of 20-30 meter in 1990 comes under the depth of 10-20 meter in 1994. Some parts of district also falls in depth range of 3-10 meter from depth 10-20 meter. 1998 data shows that there is inclination from depth of 3-10 meter to 0-3 meter in an area of about 360.46 sq kms. It may be due to heavy floods in the district in 1995 as reported by Chaudhary et al., 1999, Arya et al., 1996 that rainfall of about 600 mm was recorded in many parts of Haryana over a small period of one week from August 29-30 to September 5, 1995 and larger area in depth range of 10-20 meter in 1994 also came in depth range of 3-10 meter in 1998. The data from year 2002, 2006 and 2010 shows that most of the area of district was covered only in the depth of 3-10 meter and 10-20 meter. However in 1998, maximum area was covered in the depth range of 3-10 meter. A detailed listing of areas under different categories during these selected years is shown in Table 1.

![Average of Depth to Water Level in different years](image)

**Figure 3**: Average depth to water level in various block for years 1990, 1994, 1998, 2002, 2006, 2010 and 2014

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Depth to Water Level (m, bgl)</th>
<th>Area (in km²)</th>
</tr>
</thead>
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<tr>
<td>1</td>
<td>0 - 3</td>
<td>5.56</td>
</tr>
<tr>
<td>2</td>
<td>3.0 – 10.0</td>
<td>1583.15</td>
</tr>
<tr>
<td>3</td>
<td>10.01 – 20.0</td>
<td>2486.86</td>
</tr>
<tr>
<td>4</td>
<td>20.01 – 30.0</td>
<td>98.95</td>
</tr>
</tbody>
</table>

**Table 1**: Area under Different Groundwater Depth zones in various years

The water level fluctuation maps (Figure 5) of 1990-94, 1994-98, 1998-2002, 2002-06, 2006-10, 2010-14 interval shows that a significant area has come in depth of 3-10 meter from depth of 10-20 meter and in the depth range of 10-20 meter from 20-30 meter which shows incline trend. Water level fluctuation Map (1990-94) shows that incline trend (0.01-1.5 m, bgI) in area of 2011.12 Km² which is 48.95 % area of the whole district. Water level fluctuation Map (1994-98) shows that incline trend (1.5-3.0 m, bgI) in area of 2468.11 Km² which is 58 % area of the whole district. Water level fluctuation Maps of 1998-2002, 2002-06, 2006-10 and 2010-14 clearly indicates general trend of inclination of depth of water level. The area statistics under different zones is shown in Table 2.
Figure 4 (a): Depth to water level maps for the years 1990, 1994, 1998 and 2002
Figure 4 (b): Depth to water level maps for the years 2006, 2010, 2014
Table 2: Area under Different Groundwater Depth Fluctuation in various years

<table>
<thead>
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<td>&lt; -1.5</td>
<td>70.10</td>
<td>7.12</td>
<td>752.78</td>
<td>145.56</td>
<td>1502.34</td>
<td>100.41</td>
<td>319.86</td>
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<tr>
<td>-1.51 – 0.0</td>
<td>723.45</td>
<td>28.90</td>
<td>1596.90</td>
<td>1109.27</td>
<td>1422.18</td>
<td>513.18</td>
<td>330.22</td>
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<tr>
<td>0.01 – 1.5</td>
<td>2021.12</td>
<td>336.78</td>
<td>1692.17</td>
<td>2231.73</td>
<td>1187.95</td>
<td>2327.63</td>
<td>519.09</td>
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<tr>
<td>1.51 – 3.0</td>
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<td>59.98</td>
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<td>209.77</td>
<td>1333.62</td>
<td>22.73</td>
<td>36.97</td>
<td>2.07</td>
<td>1198.13</td>
<td>2473.88</td>
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</tbody>
</table>

Figure 6: Water level Fluctuation Map for 1990-2014 of Hisar District

Water level fluctuation map (1990-2014) indicates an area of 2473.88 Km² shows inclination trend of depth to water level. This is shown in Figure 6. Long term fluctuation map (1990-2014) shows that about 91.1% area of district falls in the range of 3-10 m. It is due to poor drafting of groundwater in the district. The dominating factors among these are poor quality of ground water in these areas. The poor quality of groundwater restricts the farmers from its use in agriculture. Groundwater quality studies conducted in Hisar district (Rani & Chaudhary, 2015) and Kaithal district (Goyal et al., 2010; Goyal and Chaudhary, 2010) also indicates an overall inclining trend in the areas having poor groundwater quality. These areas show a good network of canals and farmers mostly rely on the use of canal water for irrigation. Most prevalent method of irrigation in the area is flood irrigation which further recharges the groundwater due to return flow.
6. Conclusions

The study reflects overall inclining trend of depth to groundwater level over the study period. There is an increase of 1878 km² in the depth range of 3-10 meter from the year 1990 to 2014. In 1990, 60% of total area was covered in the depth range of 10-20 meter out of which 40% came in the depth range of 3-10 meter in 2014. An area of 85.42% of the district comprising of north-west, south-west and south-east parts shows incline trend over the study period of 1990-2014. Rising trend in average depth in the district in the year 1998 is reflected due to heavy floods which occurred in 1995. The areas showing inclining trend on long term basis (1990-2014) are the areas having poor groundwater quality. Very small area of 15.58% shows decline trend and is confined around northern portion of Hansi II block, Narnaul block and parts of Adampur Block in the district over the period 1990 to 2014. The study demonstrates the subtle use of GIS in spatial distribution mapping and monitoring for groundwater quality in the area.

References


Chaudhary, B.S., 2003: Integrated land and water resources management in southern part of Haryana using remote sensing and geographical information systems (GIS), Ph.D. Thesis, University of Rajasthan, Jaipur, India. 78-79.


