Spatio-Temporal Variations in Groundwater Levels in Jhunjhunu District

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Abstract: ***Jhunjhunu district of Rajasthan is fast depleting its groundwater resources. The annual abstraction of groundwater in this district is twice more than the annual recharge and the Central Ground Water Board (India's nodal agency for water resources) has notified seven developmental blocks of the district as overexploited and further sinking new well or deepening of existing wells has been prohibited. However, these groundwater-loss estimations are lumped averages and do not provide detailed spatial patterns of groundwater depletion. This in turn limits the development of comprehensive groundwater management plans at micro levels. In this piece of research, the spatial-temporal pattern of groundwater loss across the Jhunjhunu district is mapped using a Geographic information System. Groundwater level observations from about 200 wells across Jhunjhunu districts have been analyzed for the period 1985 to 2015. This analysis indicates that while the groundwater stocks have been completely decimated in those pockets which are underlain by hard rock aquifer, groundwater table is declining rapidly in rest of the district underlain by areas underlain by alluvial formations as well.***

Keywords:Groundwater depletion, alluvial aquifer, hard rock aquifer, spatial variation, GIS, sustainability

Introduction

Agriculture has been the predominant land use type in Jhunjhunu district of Rajasthan as more than 70% of district's total land area is cultivated every year. Jhunjhunu lacks large surface water bodies like lakes and rivers and without irrigation facilities crops could be raised only during monsoon season. Expansion of rural electrification since the decade of 1970s enabled energization of wells and abstraction groundwater in quantities sufficient for irrigation. Over the course of last four decades croplands with access to groundwater irrigation have steadily increased in number and by the year 2015 about half of districts total land area was irrigated.

However the groundwater irrigation driven intensification of agricultural landuse has caused rapid decline of groundwater levels as the annual abstraction is twice the annual recharge (CGWB, 2006). There are 8 Developmental Blocks/Panchayat Samities in Jhunjhunu district. The Central Ground Water Board (CGWB) has notified seven Panchayat Samities as 'groundwater dark zones' and further sinking of wells has been prohibited. Groundwater depletion threat has turned into a reality as some villages have completely run out of groundwater. Moreover, the discharge of wells has reduced significantly in an even larger number of villages. The number of such villages is gradually increasing and unless sustainable groundwater abstraction practices are adopted by farmers, the resources base is likely to be busted in near term.

While it is known that groundwater is depleting fast in Jhunjhunu, there are significant spatial variations in the rate of groundwater level decline and the quantum of remaining stock of groundwater resources across the district. The panchayat samiti scale averaged groundwater loss estimations do not provide detailed spatial patterns of groundwater depletion. This limits the formulation of comprehensive groundwater management plans at village panchayat scale. Detailed maps of aquifer characteristics and spatial pattern of groundwater levels are an essential prerequisite for formulation of sustainable groundwater use plans. In this piece of research, the spatial-temporal pattern of groundwater loss across the Jhunjhunu district is mapped using a Geographic information System.

Objective

Mapping thespatio-temporal variations in groundwater levels across the Jhunjhunu district during the period 1985-2015.

Data Sets following data sets have been used:

- In-situ 'depth to groundwater level'measurements for the period 1985 to 2015 from the monitoring wells under purview of the State Ground Water Department (SGWD).
- Aquifer Typology map prepared by the Central Ground Water Department (CGWD).
- District Statistical Outline booklets (1980-2015) .
- Jhunjhunu District Gazetteer

Methods

Groundwater level at any place is the in-situ measurement of the depth at which water is encountered in a well in any area. The SGWD each year observes the groundwater level in about 100 wells located across Jhunjhunu. The location of these monitoring wells spread across Jhunjhunu district was ascertained with help of Google Earth and mapped. Information on the changes in depth to groundwater level in each of these monitoring wells since 1985 was attached to map in form of attribute table. Subsequently, the values of depth to groundwater below the surface were interpolated using spatial analyst tools of ArcGIS software for creating 'Depth to Groundwater Table' maps for the years 1985, 1995, 2005 and 2015.

Results and Discussion

As per the Central Ground Water Board (2008), two kinds of aquifer types are found in Jhunjhunu:

(a) Alluvium water bearing formations: Alluvium composed of sand, silt, clay, kankar and gravel is the principal water bearing formation in Jhunjhunu and occupies about 78.7 % of district's area. These formations occupy western, northern, central, and southern parts of district. Exploratory borehole data has revealed the presence of aquifer system down to 60 - 120 meter in the alluvial formations. The alluvial aquifer formation has been classified into two sub-categories based on the basis of geological age of alluvium: 'Older Alluvium' which accounts for most of the alluvial water bearing formation; and 'Younger Alluvium' restricted to the beds of seasonal streams Kantli and Dohan.

(b) Hard-rock water bearing formations: Hard-rocks like quartzite, schist, phylllite, gneisses, limestone granites, amphibolites form the ancillary aquifer and occupy about 22% area in the south eastern parts of district covering Khetri, Udaipurwati and Buhana blocks. Most of the hard-rock aquifer has a rich cleavage of joints and fractures. Within the hard-rock aquifer, impermeable rocky hills bereft of soil or weathered material also occur. These hilly zones have been designated by the CGWB and SGWD as no aquifer zones. Kantli river bifurcates the hard-rock aquifer into two parts. In the hard rock area the soil layer or water bearing formation is very thin ranging between 1-10 meters of ground strata. Below the soil layer are found the weathered strata of rocks ranging in thickness from 5 to 60 m. These water bearing formations broadly follow the pattern of surface topography; the lower ground is occupied by alluvial formations while hard-rock aquifer is restricted to the higher ground. The distribution of these aquifer units across different Panchayat Samities is given in Figure 1.

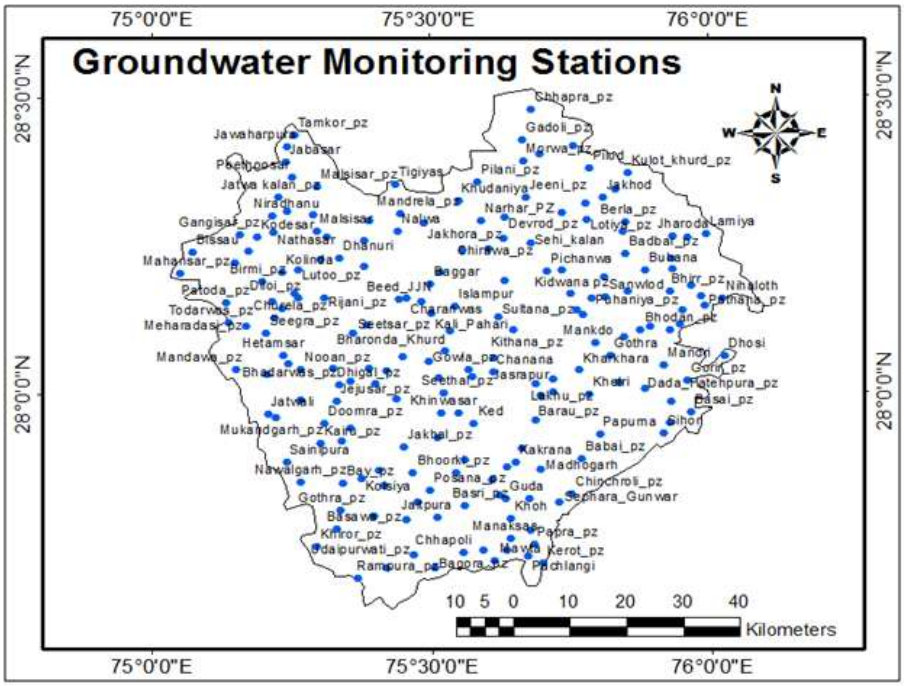
Figure 1: Spatial extent of aquifer units in different panchayat samities of Jhunjhunu.

Groundwater Level Monitoring Network

Monitoring of groundwater levels across the state was initiated in 1984 under the aegis of the CGWB and the SGWD. In the 1980s and early 1990s, in-situ groundwater levels data were collected from either public wells used for drawing drinking water or irrigation wells used by farmers. However due to decline of groundwater level, most of the wells functional in the 1980s and 1990s dried up by early 2000s. Wherever an observation well dries out, the SGWD identifies an alternative functioning well in the same or nearby village. Since the late nineties, SGWD has also started construction of peizometers for creating a more reliable groundwater monitoring network. Till date, about 200 wells located in different villages scattered across Jhunjhunu have been used for collecting groundwater level data. In the year 2015, about 92 monitoring stations were functional.

Although a continuous record of groundwater table levels for each of the wells is not available, the available data sets provide a fairly representative picture of declining groundwater levels. These data sets were made available by the SGWD for the purposes of this research (SGWB, 2015; Personal Communication, Mr. Kumbha Ram Dogiwal, Chief Hydrologist, Jhunjhunu). In these groundwater level data sets, the location of monitoring wells has been specified with reference to the topographic sheet number and name of village. We have used this information in conjunction with Google Earth for ascertaining the location of monitoring wells in terms of latitude and longitude. With the help of location details, a geographically referenced map of the monitoring wells/peizometers was prepared (Figure 2).

Figure 2: Groundwater monitoring stations.



Depth to Groundwater Table

Prior to 1970, most of farmers of Jhunjhunu district were solely dependent upon monsoon rains for raising crops and their livelihoods. Irrigated crops were confined to the foot of Aravalli hills and beds of Kantli and Dohan rivers, where groundwater could be tapped from shallow depths ~ 5-10 meters with aid of animal traction (DoDG, 1984). Expansion of rural electrification allowed tapping of groundwater from greater depths in aquifer. The number of energized wells has rapidly soared from less than 3000 in the early seventies to above 45000 in 2015. The increase in the number wells at an interval of five years is given below in Table 1.

Table 1: Increase in the number of wells in Jhunjhunu during 1970 - 2015.

Year	Total No of Wells	In Use	Out of use	Energized
1970	11493	7137	4356	2896
1975	15256	9666	5590	4701
1980	20969	14700	5996	11522
1985	23631	20626	3005	19281
1990	30125	25010	4607	21765
1995	34742	30912	3830	27636
2000	42737	39878	2859	35503
2005	46989	42240	4749	40969
2010	47554	41202	6352	42050
2015	59436	47229	12207	46800

[Source: DoDG, 1984; DoES, 1980 to 2015**]**

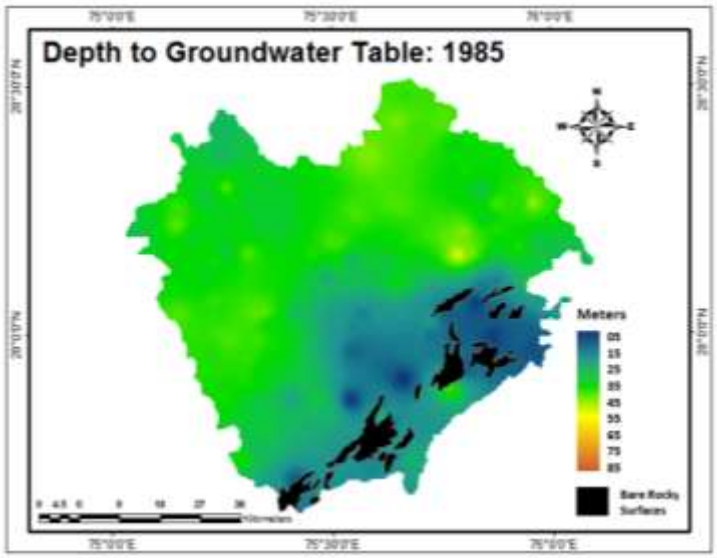
The total number of wells in Jhunjhunu in 1970 was 11493. Out of these, 7137 were in use and 2896 were energized. By 1985 the total number almost doubled. Out of these 20626 were in use and 19281 were energized. By the turn of century, the number of well increased to 42737. Among these 39878 were in use and about 35503 were energized. In the next fifteen years the total number of well rose to 59436, out of which 47229 were functional.

It is obvious from the table that wells are going out of use in large numbers. As the number of wells increased, the depth of groundwater level in wells from the surface started declining and with passage of time more and more wells became dysfunctional due to decline in groundwater level. Declining groundwater levels have renders shallow wells dry. Till the year 2000, the number of out of use wells fluctuated up and down. That indicates that wherever the wells became dysfunctional due to decline of groundwater level, farmers drilled deeper and often wells became functional again. However, after the year 2000 the number of out of use well is rising very sharply and it seems that the groundwater stocks in many localities have been decimated in the sense of yielding sufficient amount of groundwater for irrigation and the strategy of drilling deeper for accessing groundwater has run its course in many areas.

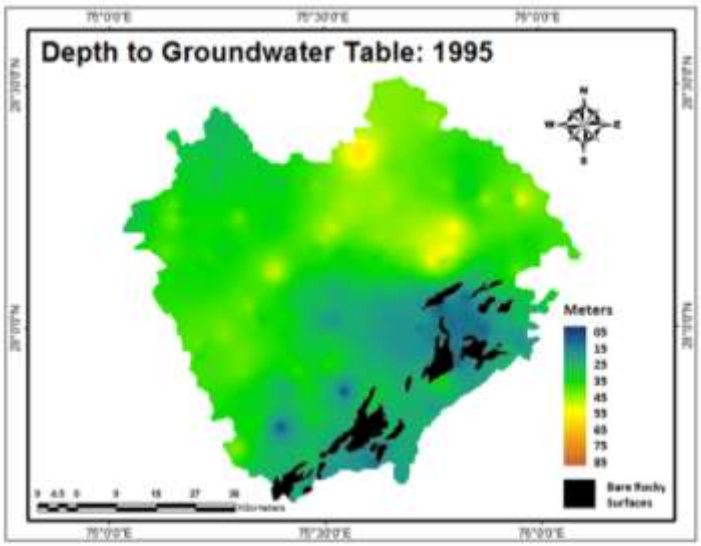
Since groundwater is a resource with spatial dimension, i.e. the groundwater stocks and levels vary substantially between areas, the analysis of groundwater development and decline is best conducted with use of maps. The depth to groundwater table maps were created by interpolating the groundwater level data collected by the SGWD for the years 1985, 1995, 2005 and 2015 (Figure 3 to Figure 6). In these maps, Blue shades indicates groundwater closer to surface (i.e. 0 to 15 meters), Green shades indicate that groundwater can be accessed from depths 15

to 45 meters, Yellow indicates that groundwater is encountered at 45 to 60 meter depths, and the Brown shades indicate that groundwater is encountered at depths between 60 to 85 meters.

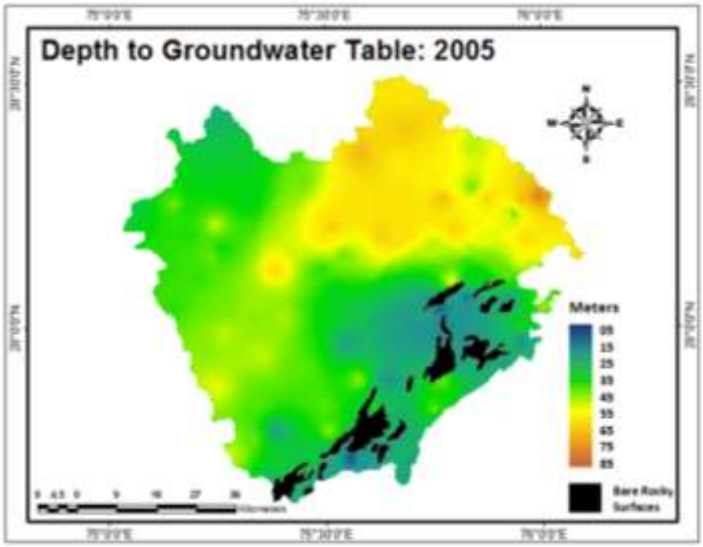
In the year 1985, the depth to groundwater table from surface for entire district varied between 6 to 51 meters, mean being 30.9 meters (Figure 3). Shades of Blue in the hard rock aquifers area and that of Green dominate entire alluvium aquifer area of Jhunjhunu. At that time, on an average groundwater could be tapped at depth less than 15 meters in Khetri panchayat samiti and 36 meters in Surajgarh panchayat samiti. In the hard rock aquifer, depth to groundwater was only 7 meters at Guda-gorgi and Gadla-kalan villages in Udaipurwati panchayat samiti areas. Groundwater table was 11 meters deep in Kherti town. Groundwater was encountered at greater depths in alluvium aquifer area: at 51 meters in Puhania village (Buhana);at 45 meters in Pilani (Surajgarh); at 42 meters in Chirawa; at 35 meters in Todarwas (Jhunjhunu); 39 meters at Mukundagrh (Nawalgarh); and at 30 meters in Mahensar (Alsisar).



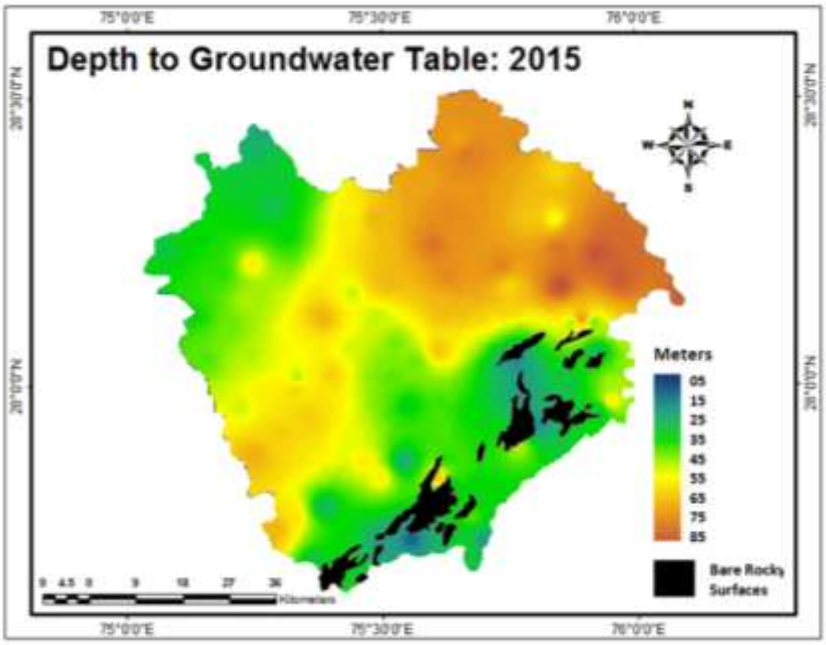
By 1995, the overall average groundwater levels decline for the district was 3.5 meter. However, there were significant spatial variations. As seen from Figure 4, Green shades replaced 'Blue' shades in the hard rock area and 'yellow' shades emerged at few places in Surajgarh and Buhana.



Over the course of following ten years groundwater table levels witnessed sharp decline in Khetri, Udaipurwati, and Buhana and Surajgarh panchayat samiti areas. Groundwater resource stock was completely depleted from the hard rock aquifers (Figure 5). The mean groundwater depth for the entire district receded from 35 to 41.6 meters between the years 1005 to 2005, a decline of more than 6 meters in 10 year duration. Yellow shades emerged in Buhana, Surajgarh and Chirawa. The rate of decline varied sharply among the panchayat samities: Buhana (13 meters); Surajgarh and Jhunjhunu (12 meters); Chirawa (11 meters); Khetri (8 meters); Nawalgarh (4 meters); Udaipurwati (2 meters); and Alsisar (-0.1 meter). Groundwater over a very large chunk of Alsisar panchayat samiti is saline and not fit for human consumption or irrigation. Hence there was not much of abstraction.

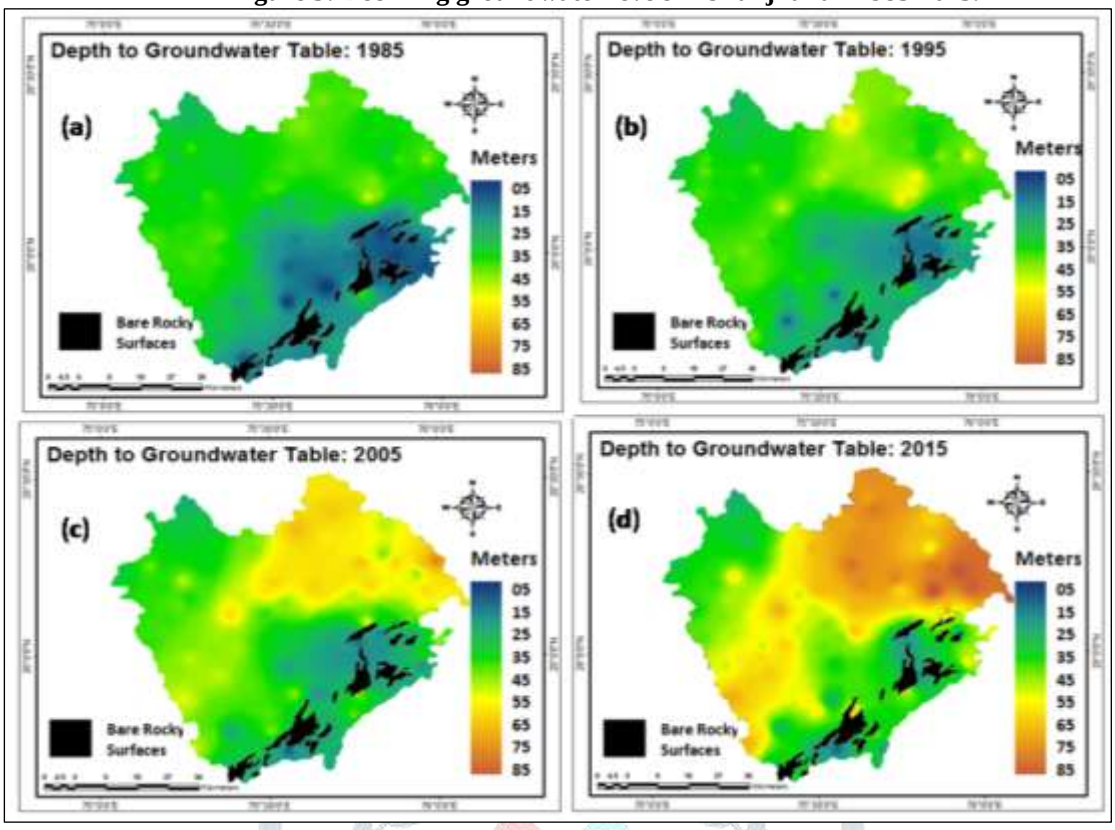


By 2015, the average depth to groundwater table touched 50.6 meters, a huge decline of about 9 meters over a decade (Figure 6). Average decline across the panchayat samities were: Buhana (14 meters); Surajgarh (12 meters); Khetri (12 meters); Udaipurwati (11 meters); Chirawa (11 meters); Jhunjhunu (6 meters); Nawalgarh (7 meters); and Alsisar (0.5 meter). During the period 2005 to 2015, groundwater depletion crisis has assumed serious proportions in some villages underlain by older alluvium aquifer as well, especially in Buhana and Surajgarh, where groundwater levels declined very sharply. In Figure 6, it can be seen dark 'brown' shades have overtaken large parts of Buhana, Surajgarh and Chirawa panchayat samities, while 'yellow' shades have emerged in parts of Nawalgarh and Jhunjhunu panchayat samities.



. Overall, it can be inferred that as the number of energized wells abstracting groundwater for irrigation have increased in Jhunjhunu, the groundwater levels have concomitantly declined. Figures 4 to 7 portray unfolding of this process across the length and breadth of Jhunjhunu establish that the rate of decline is highly variable among different parts of Jhunjhunu.

Figure 3: Declining groundwater levels in Jhunjhunu - 1985-2015.



(Source: Groundwater level data made available by the SGWD (2015) and maps created by author)

Conclusion

The integration of topographic sheet number and the coordinate positions accessed from Google Earth enabled creation of a spatially referenced point scale 'Groundwater Monitoring Network' map of Jhunjhunu district. This map was in turn used for interpolating the spatially variable groundwater levels at these point locations. The 'Depth to Groundwater Level' maps (Figure 3 to Figure 6) provide a fairly accurate quantification of the ongoing groundwater depletion in Jhunjhunu district in a spatially disaggrgated fashion over the course of last thirty years.

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