Eco. Env. & Cons. 28 (1) : 2022; pp. (277-283)
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ISSN 0971–765X

DOI No.: http://doi.org/10.53550/EEC.2022.v28i01.040

Decadal Groundwater Level Changes in Pratapgarh District of Southern Rajasthan, India

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(Received 21 May, 2021; Accepted 26 June, 2021)

ABSTRACT

The higher dependency on the groundwater has increased extremely over time due to over-utilization of the aquifers. Thus, it is urgent to assess the degree of exploitation and analyze the groundwater level trend in the area of interest. This study has been taken to examine the pre and post -monsoon groundwater level fluctuations using statistical methods for 76 observation wells in Pratapgarh district of Rajasthan for the last 11 years (2009-2019). Results revealed that the groundwater level has fallen general to significantly in maximum number of blocks during 2009-2019. It was found that the resulting groundwater levels are linearly affected by the amount of rainfall occurred. The groundwater level fluctuations data considerably interprets the groundwater recharge. The average annual decline in groundwater level was detected with strong decline (0.204 m/yr) during post-monsoon season at Chhoti Sadriblock. The average rate of rise and decline during pre and post monsoon groundwater level for the Pratapgarh district was 0.110 m/yr and 0.081m/yr, respectively. In spite of being a predominantly hard rock area, the district shows limited variation in depth to groundwater level. The alterations in water level in different seasons may be attributed to the recharge by rainfall in post-monsoon season.

Keywords: *Groundwater, Water level Fluctuation, Rainfall, Hard rock, Recharge, F-test, Southern Rajasthan*

Introduction

In recent years, groundwater extraction have increased severely and is consistently reported worldwide (Van *et al.*, 2010). overexploitation of groundwater resources may cause serious declines in water levels Aggarwal *et al.*, 2009). The groundwater scenario in semi-arid and humid regions due to availability of basaltic geology of central and western part of India is highly dynamic, where water level rises quickly to recharge in the monsoon season (Gautam *et al.*, 2020) and declined when pumping is done in post-monsoon season. The study was conducted to analyze the change in groundwater levels in different blocks of Pratapgarh district, Rajasthan. Monitoring of groundwater periodically may be represented as an effective tool for better management, planning of this precious resource.

In Southern Rajasthan, particularly in Pratapgarh district, the dependency on groundwater resources is a major concern. Therefore,study of relationship between rainfall variability and groundwater levels is very important for its judicious utilization. The Pratapgarh district is predominantly hilly with hills occupying about 30% of district area, aquifer have formed in weathered, fractured and jointed hard rock which contains good quantity and quality of water plz add the citation (Gautam and Awasthi, 2020) and (Gautam *et al.*, 2021).

Study Area

Pratapgarh district is located in the southern part of Rajasthan. It stretches between 23° 31' 49.84'' to 24° 30' 16.57'' north latitude and 74° 13' 19.93'' to 74° 58'

59.58'' east longitude covering area of 4,400.7 km^2. The district is systematically drained by three prominent rivers and major part 'Mahi River Basin' whereas the north-south extending strips in the eastern border is part of 'Chambal River Basin' and the small part in the north is part of 'Banas River Basin'. The normal annual rainfall is 896.2 mm. The climate of Pratapgarh district is more similar to Madhya Pradesh than to typically sub-humid region of Rajasthan. The district exposes rocks belonging to Aravalli and Vindhyan Super Groups. The major part of the district has basalt and the availability of highly fertile Black Cotton Soil is made of molten magma. Location map of Pratapgarh district is presented in Fig. 1. Chhoti Sadri and Pratapgarh come under the upper side of Jakham dam, while Arnod, Dhariyawaad and Peepalkhunt come under downstream side of the dam.

Data Collected

The groundwater level data of 76 observations well for five blocks viz., Arnod. Peepalkhoon, Chhoti sadari, Partapgarh and Dhaiyawad of Pratapgarh district during the pre and post-monsoon seasons for a period of 11 years (2009-2019) was used in the study. The Groundwater data have been collected from RGWD, Udaipur, Rajasthan. Daily rainfall data (2009–2019) for the study area were obtained from Rajasthan Water Resource Department. The groundwater and rainfall data as recorded seasonally and interpreted graphically to understand the relation between rainfall and dynamics of groundwater. The entire data sets are analyzed in to two-parts, i.e., pre-monsoon and post-monsoon.

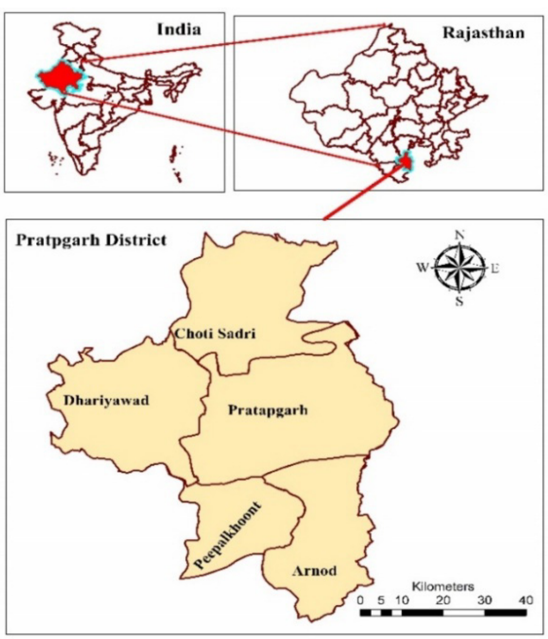

Fig. 1. Location map of Pratapgarh district

Materials and Methods

Water level fluctuation was analyzed seasonally as well as decade. The relationship between rainfall and groundwater was described using linear regression analysis.

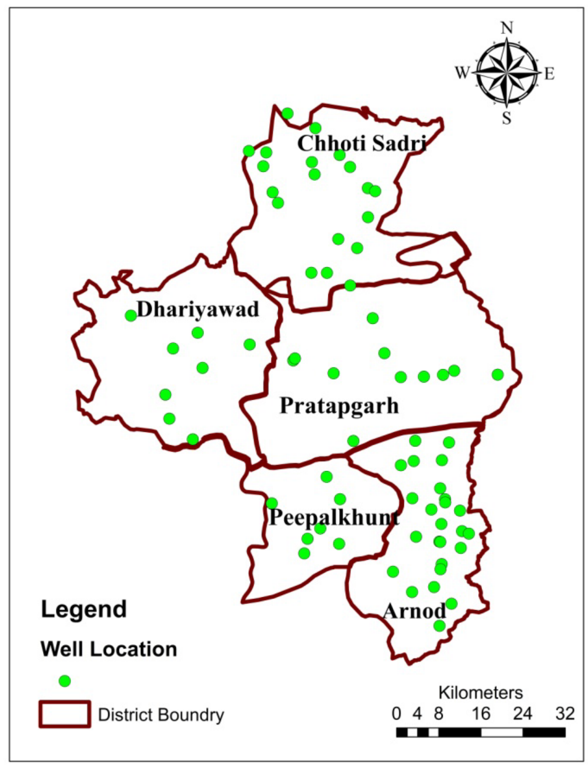

Fig. 2.Location of wells

F-Test

In agricultural experiments, like groundwater level and recharge fluctuations, mean as well as variability is also a main parameter to assess the performance of an operation. Hence, it attracts researchers' attention to compare and correlate the variability of two populations (Snedecor, 1934). During testing, hypothesis of equality of variances, the greater and lower variance is always put in the numerator and denominator, respectively. Equality of two population variances and regression coefficients was tested by F- Test. A known distribution is followed by the sampling distributions of the ratio of variances. We can do hypothesis tests using the ratio of variances. The range of F is 0 to ".

$$F = \frac{\text{Larger Sample Variane}}{\text{Smaller Sample Variance}}$$

Let x_1 , x_2 ,...x_n and y_1 , y_2,...y_n are two independent random samples with size n_1 and n_2 drawn from two normal populations N (μ_1,$\sigma_1^{2)}$ and N (μ_2,σ_2^2) respectively. S_1^2 and S_2^2 are the sample variances of the two samples.

Null hypothesis H_0: $\sigma_1^2 = \sigma_2^2$

Under H_0, the test statistic becomes $F = S_2^2 / S_1^2$ $S_1^2 > S_2^2$

Which follows F-distribution with (n_2-1, n_1-1) d.f.

$$S_1^2 = \frac{1}{n_1 - 1}\left[\sum x^2 - \frac{\Sigma(x)^2}{n_1}\right] \text{ and}$$

$$S_2^2 = \frac{1}{n_2 - 1}\left[\sum y^2 - \frac{\Sigma(y)^2}{n_2}\right]$$

Which follows F-distribution with (n_2-1, n_1-1) d.f.

If calculated value of F is less than table value of F with (n_2-1, n_1-1) degree of freedom at identified level of significance, then the null hypothesis will be accepted and therefore we may conclude the homogeneity of variances of the populations, otherwise it will be heterogeneous in nature. F-test is the ratio of two samples variance, when two sample variance are very adjacent to identical, the F score will be adjacent to one. If the F value close to one, hypothesis of the sample that come from populations with the same variance should be accepted. If the F score is away from one, then it should be concluded that populations probably have different variance. Formally two hypothesis are required to complete the test. The first is null hypothesis that there is no difference and denoted as H_0. The second is that there is difference, and known as alternative hypothesis and denoted by H_1.

The F- test was used for instance in parametric ANOVA to identify difference in the population means of pre and post –monsoon data at different observation wells.

Results and Discussion

Relationship between Rainfall and Groundwater

The result showed that rainfall was not only the factor influencing the groundwater fluctuations. Other Factors which might have influenced the ground water level includes the land cover, because major part of Pratapgarh district is covered by hilly rocks as compared to vegetation. Ground water levels are affected by the amount of rainfall and its analysis to improve recharge and reduce groundwater over-utilization. The plots between rainfall and groundwater level data shows moderate uphill (+) correlation.

The F- test was performed for the pre and post monsoon groundwater levels for all five blocks of the district. The average groundwater level data were used for the analysis over the study period. The test statistics is given in the Table 2a and 2b. The F-test was performed to compare the significant changes in the two different seasons.

At Arnod, Chhoti Sadri, Dhariyawad, Pratpgarh and Peepalkhunt block, F_{stat} value forpre and post monsoon was found 1.342,1.226, 1.344,2.817 and 1.094 whereas, $F_{critical}$ value were 2.978, 2.978, 2.978,2.978 and 2.978. Therefore, there is no significant change in the groundwater level because test result shows that, $F_{stat} < F_{critical}$ for all the blocks of dis-

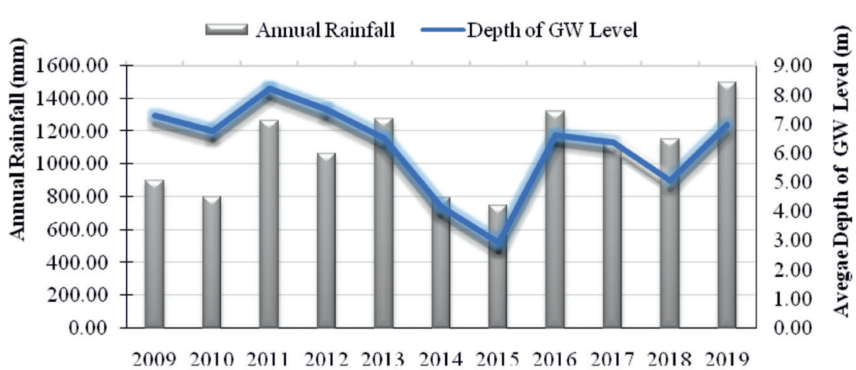

Fig. 3. The relation between annual rainfall and depth of groundwater levels

Table 2a. Average water table, m for pre and post monsoon season

S. No.	Chhoti Sadri		Arnod		Dhariyawad	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1.	14.05	4.40	11.09	4.03	9.65	4.72
2.	12.64	6.66	11.12	4.64	9.45	5.85
3.	16.67	4.55	10.41	2.79	8.97	3.61
4.	16.56	4.30	9.01	3.98	7.17	3.23
5.	15.77	6.17	9.51	4.19	7.63	4.81
6.	14.86	7.65	9.75	4.45	7.99	5.27
7.	14.58	6.25	9.28	5.62	7.32	4.81
8.	17.62	5.67	10.14	4.96	8.75	5.03
9.	17.26	5.88	10.39	3.63	8.29	4.70
10.	16.35	7.23	9.08	5.67	7.71	6.05
11.	16.24	8.09	8.50	5.91	7.70	5.21
Mean	15.69	6.07	4.53	9.84	8.23	4.843
Variance	2.25	1.67	0.90	0.74	0.72	0.69
F_{stat}	1.342		1.226		1.344	
P(F<=f)	0.322		0.376		0.324	
$F_{critical}$	2.978		2.978		2.978	

Table 2b. Average water table, m for pre and post monsoon season

S. No.	Pratapgarh		Peepalkhoont	
	Pre Monsoon	Post Monsoon	Pre Monsoon	Post Monsoon
1.	12.12	6.89	9.19	6.02
2.	10.00	5.39	9.50	5.69
3.	11.20	4.38	9.09	4.51
4.	10.21	5.98	7.96	3.86
5.	10.15	3.78	6.98	2.94
6.	10.96	6.58	8.10	4.05
7.	10.95	7.06	7.62	4.59
8.	12.69	5.78	9.14	4.56
9.	12.22	4.80	9.23	3.75
10.	11.68	7.81	8.03	5.35
11.	11.71	8.89	7.52	4.50
Mean	4.529	8.396	6.121	11.264
Variance	0.806	0.736	2.313	0.821
F_{stat}	2.817		1.094	
P(F<=f)	0.058		0.444	
$F_{critical}$	2.978		2.978	

Table 3. Average rate of fluctuation of groundwater (2009-2019)

S.N.	Name of Block	Pre-Monsoon (m/year)	Post-Monsoon (m/year)
1.	Arnod	0.258 ↑	0.057 ↓
2.	Chhoti Sadri	0.180 ↓	0.204 ↓
3.	Dhariyawad	0.207 ↑	0.069 ↓
4.	Pratapgarh	0.093 ↓	0.086 ↓
5.	Peepalkhunt	0.173 ↑	0.126 ↑
6.	Pratapgarh District	0.110 ↓	0.081 ↓

(Rise-↑, Decline-↓)

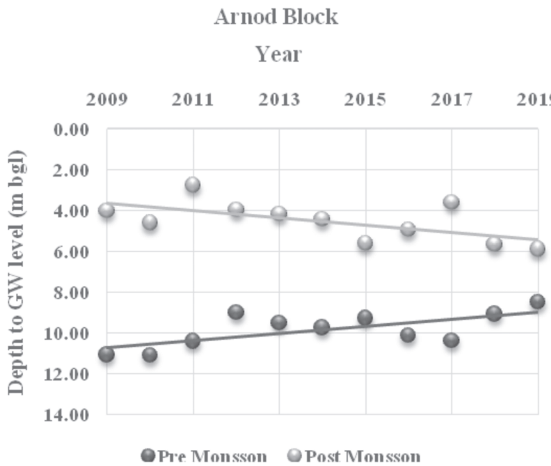

Fig. 4a. Average depth of Groundwater level in Arnod block (2009-2019)

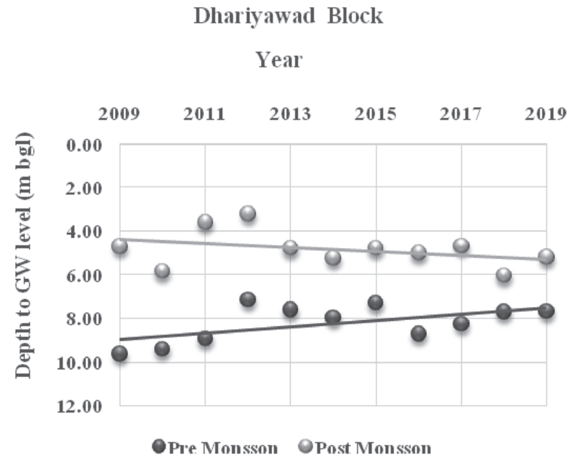

Fig 4c. Average depth of Groundwater level in level in Dhariyawad block (2009-2019)

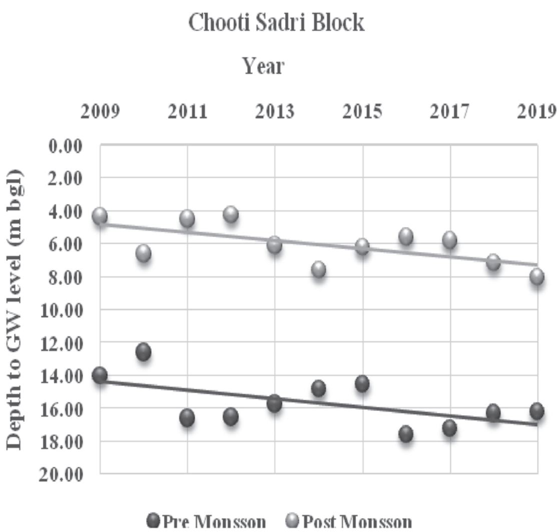

Fig. 4b. Average depth of Groundwater level in Chhoti Sadri block (2009-2019)

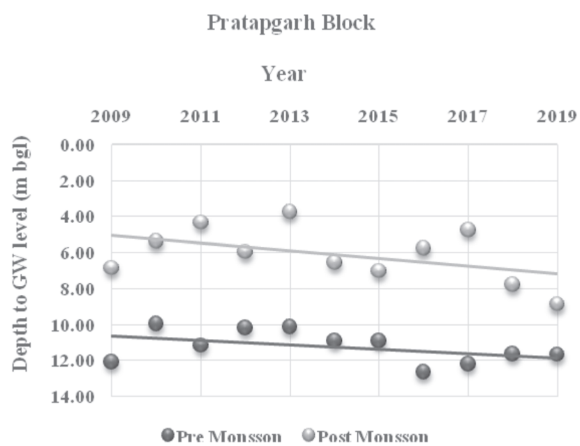

Fig 4d. Average depth of Groundwater Pratapgarh block (2009-2019)

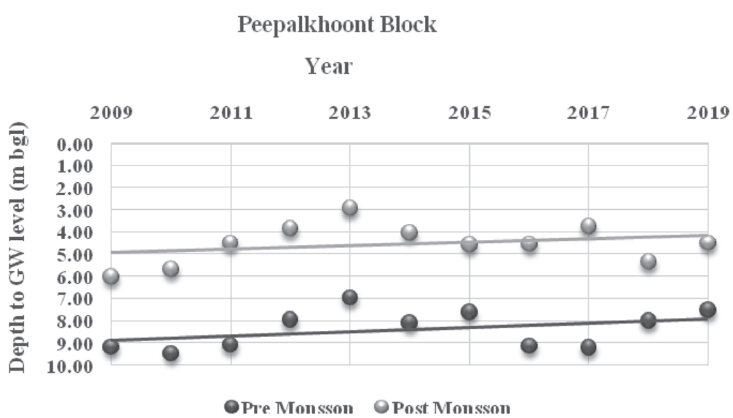

Fig. 4e. Average depth of Groundwater level in Peepalkhunt block (2009-2019)

trict. This analysis will help to identify the critical blocks where, rate of groundwater levels is declining over the years. Declining scenario at Chhoti Sadri and Pratapgarh block has been observed and presented in the Fig. 4b and 4d.

The result of change in the rate of groundwater fluctuation during 2009-2019 is presented in the Table 3 and these results are showing some significant facts. The fall in the water level was observed during pre-monsoon season in Chhoti Sadri (0.180 m/year) and Pratapgarh (0.093 m/year) block. In the post-monsoon period maximum number of blocks as Arnod (0.057 m/yr), Chhoti Sadri (0.204 m/yr), Dhariyawad (0.069 m/yr) and Pratapgarh (0.086 m/yr) shows a downward direction. Meanwhile, four blocks of district for pre-monsoon viz. Arnod (0.258 m/yr), Dhariyawad (0.207 m/yr), Peepalkhunt (0.173 m/yr). In post-monsoon period water level declines in all the blocks except Peepalkhunt (0.126 m/yr). Besides, the highest rate of rise and fall in the groundwater for Pratpgarh was observed in Arnod block (0.258 m/yr) and Chhoti Sadri (0.204 m/yr) in between 2011 to 2016.

It was revealed that the groundwater declining gradually in Chhoti Sadri and Pratapgarh block of district. Both blocks fal l into the upstream sideof the canal, while the other blocks come under downstream side. The reason behind is over-dependency on the groundwater uses in these blocks. Furthermore, groundwater level has improved in Peepalkhunt block on, 0.173 m/year for pre-monsoon and 0.126 m/year for post-monsoon season.

Conclusion

The study aims to understand, behavior of groundwater level over a decade.The groundwater levels were observed for pre and post season over five blocks of Pratapgarh district using F-test statistical analysis. The maximum decline in ground water level has been reported at Chhoti Sadri block (0.204 m/yr) during post- monsoon followed by rest of three blocks viz. Arnod, Pratapgarh, Dhariyawad. The Peepalkhuntblock has shown positive trend with 0.173 m/year for pre-monsoon and 0.126 m/year for post-monsoon season. In combine term, Pratapgarh district was showing rising trend for pre-monsoon, whereas in post-monsoon it was declining. The groundwater level is declining up to 0.057 m/year in most of the blocks. In results it is also seen that the groundwater level has decreased in the areas of canal unavailability. The study concludes that the inappropriate withdrawal of groundwater is a major cause of declining trend in the blocks, so attempts should be made towards aquifer recharge in this part of study area and over-utilization should be restricted under dynamic recharge zone.

Acknowledgement

The authors are greatfull to the District Groundwater, Department and Water resources department, Jaipur for their extensive help and support during data collection and field survey. The authors also extend gratitude towards editor and anonymous reviewers of the journal for their fruitful and very effective comments, which has led to noteworthy improvement to the manuscript.

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