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Seasonal and annual trend analysis of ground water status in different districts under Bastar plateau and Northern hill zone of Chhattisgarh

Keerti Kumar, GK Das, HV Puranik and Manoj Kumar Beck

Keerti Kumar
Department of Agrometeorology, IGKV, Raipur, Chhattisgarh, India

GK Das
Department of Agrometeorology, IGKV, Raipur, Chhattisgarh, India

HV Puranik
Department of Agrometeorology, IGKV, Raipur, Chhattisgarh, India

Manoj Kumar Beck
Department of Agrometeorology, IGKV, Raipur, Chhattisgarh, India

Corresponding Author
Keerti Kumar
Department of Agrometeorology, IGKV, Raipur, Chhattisgarh, India

Abstract
Study was carried out the trend of groundwater status for 11 districts of Bastar plateau and Northern hill zone of Chhattisgarh. Long term groundwater level data of 27 years (1993-2019) were collected from Central Ground Water Board, Raipur (Chhattisgarh). The trend analysis of ground water level was computed with the help of Mann-Kendall method and linear trend graph method. Results were revealed that outcome of trend analysis of ground water level indicates that five districts reported significantly increasing trend of ground water at 1% level of significance *i.e.* Sukma, Bijapur, Jashpur, Surguja and Balrampur district whereas Kondagaon and Surajpur district showed significant increasing trend at 10% level of significance. Remaining four districts the depth of ground water level was increasing but observed it was non-significant. *i.e.* Koria district while Bastar, Dantewada and Narayanpur districts. The status of ground water level in most of the districts *i.e.* Sukma, Bijapur, Kondagaon, Jashpur, Surguja, Balrampur and Surajpur recorded significantly increasing trend of groundwater level mean ground water level was going down.

Keywords: Trend analysis, groundwater depth, Bastar plateau, northern hill zone, Mann-Kendall and linear trend graph method

Introduction
Groundwater is the most valuable natural resource available free of cost in the earth. The major and the preferred source of drinking water in rural as well as urban areas is ground water which cater to 80% of the total drinking water requirement and 50% of the agricultural requirements of rural India. There for it is important to understand that the fluctuation of groundwater levels with reference to natural or artificial recharge in space and time domain. The rainfall is an important component of the water cycle and is the prime source of groundwater recharge. The exploitation of groundwater has increased greatly for agricultural, industries and domestic needs because large parts of the country have little access to rainfall due to frequent failures of monsoon. That too receives their major portion during south-west monsoon (Tirkey *et al.*, 2012) [14]. The total ground water of Chhattisgarh states is 14.83 billion cubic meter and Net annual available groundwater is 13.68 billion cubic meters with annual draft for irrigation, domestic and industries sectors are 2.80 bcm out of which annual draft in irrigation sector is 2.31 bcm. The available ground water (12.03 bcm) is untapped in the state due to several constraints. One of the major constraints is rural electrification at farm site and number of developed ground water structure (shallow tube wells, bore well and open well).

In Bastar Plateau Zone available ground water resources for the district are in the order of 1098.57 mcm and the ground water draft is 116.67 mcm. The stage of ground water development was only 10.62%. It is estimated that with the available ground water resources, a total of 42,204 dug wells and 45,018 bore wells can be constructed in the district. Nearly 97% of the area is drained by Indravati River and Sabari River, which are tributary to Godavari River. The remaining 3% of the area is drained by Mahanadi River in the extreme northern part of the district with Hatkul tributary (Soni, 2013) [11].

Northern hills zone area 23.52 lakh hectares which comprises 25.15% of the total geographical area of the state. The normal annual rainfall is 1270 mm. The net annual ground water availability was 2.73 billion cubic meter. The gross annual draft was estimate as 0.52% billion cubic meter, out of which existing gross groundwater draft for irrigation was 0.44 billion cubic meters and existing gross ground water draft for domestic and industrial purpose was 0.07.

billion cubic meters, 2.16 billion Cubic meter of the net ground water available for future irrigation development (Anonymous, 2020). There is needed to develop irrigation plan and underground water recharge for the Bastar plateau and Northern hills zone of Chhattisgarh.

Material and Methods

Study area

Chhattisgarh is located in the east central part of the country, between 17 °46' N and 24 ° 06' N latitude and 80 ° 15' to 84 ° 24'E longitude. The present study was carried out in Bastar plateau and Northern hills zone covering 11 districts of Chhattisgarh state. *viz*. Bastar, Sukma, Bijapur, Narayanpur, Dantewada, Kondagoan, Sarguja, Jashpur, Balrampur, Surajpur and Koria districts.

Groundwater data

Block wise / districts wise long term ground water data was collected from the office of Regional office Central Ground Water Board Raipur, for Bastar plateau and Northern hill zone of Chhattisgarh, as per availability (1993-2019). Ground water levels are being measured by Central Ground Water Board four times a year during January, April/ May, August and November. The ground water status was categorized into four major season namely non-monsoon (January-April), pre-monsoon (May-July), monsoon (August-Oct), post monsoon *kharif* (November-December) in a year. These four seasons are averaged to obtain average annual ground water status for each district in Bastar plateau and Northern hill zone.

Method description

Trend analysis

Trend analysis is method of collecting information and attempting to find out a pattern or trend from that information. This method is based on the time series data where information (data) in sequence is plotted against time (significantly long period) to detect general pattern of a relationship between time and information (factor).

The Mann-Kendall test is a non-parametric test used to identify trend in time series data. The test was suggested by Mann (1945) and has been extensively used with environment time series by Hipel and McLeod, 2005. The test compares the relative magnitude of sample data rather than data value them. One benefit of this test is that the data need not confirm to any particular distribution. Let X_1, X_2 ……………….X_n represent n data points where X_j represent the data point at time j. Then the Mann-Kendall statistics (S) is given by

$$S = \sum\sum Sign\ (X_j - X_k)$$
$$j = 2, 3....... n;$$
$$k = 1, 2...... j-1$$

Where

$$Sign\ (X_j - X_k) = 1 \text{ if } X_j - X_k > 0$$
$$= 0 \text{ if } X_j - X_k = 0$$
$$= -1 \text{ if } X_j - X_k < 0$$

A very high positive value of S is an indicator of an increasing trend and a very low negative value indicates a negative trend. However, it is necessary to compute the probability associated with S and the sample size n, to quantify the significance of the trend. For a sample size > 10, normal approximations to the Mann-Kendall test may be used.

Then standardized statistical test is computed by:

$$Z = S-1/V(S) \text{ if } S>0$$
$$= 0 \text{ if } S = 0$$
$$= S+1/V(S) \text{ if } S<0$$

The presence of a significant trend is evaluated using Z value.

Result and Discussion

Annual trend analysis of Groundwater depth

Long term 27 years (1993-2019) groundwater level data of Baster plateau and Northern hill zone of Chhattisgarh is presented in Table-1, Table-2 and Table-3. Bastar district recorded maximum ground water depth with value of 5.75 mbgl and minimum value of 3.53 mbgl was recorded during 2010 and 2014 respectively. In both the methods annual ground water trend was decreasing but it was non-significant table 3. Dantewada district maximum ground water level was 6.83 mbgl (2016) whereas Minimum level was 3.25 mbgl (2007) with the non-significant decreasing trend on annual basis in both the methods table 3. Narayanpur district maximum level of ground water was 3.81 mbgl (2016) while minimum value was 1.96 mbgl (2015). In both the methods annual ground water trend was decreasing but it was non-significant table 3. Sukma district recorded maximum depth of ground water level was 7.12 mbgl (2014) while minimum depth was 5.32 mbgl (2000) and it was significantly increasing under both the methods of study on annual basis table 3. Bijapur district maximum and minimum ground water level was 5.98 mbgl and 3.62 mbgl during 2003 and 1995 respectively. Significantly increasing trend of ground water level was recorded in Mann-Kendall trend method, while it was non-significant in linear trend graph method table 3. Kondagaon district maximum depth of ground water level was 5.9 mbgl and minimum was 3.7 mbgl during 2003 and 2004 respectively. On annual basis significantly increasing trend of ground water level was recorded in both the methods table 3.

Jashpur district maximum level of annual ground water was 5.67 mbgl (2016) and minimum was 3.42 mbgl (1999) with the significantly increasing trend under both the methods. Surguja district maximum ground water level was 6.94 mbgl (2016) while minimum was 4.03 mbgl (1995). Yearly analyses carried out, with the help of Mann-Kendall test method and linear trend graph method reported significantly increasing trend of ground water level. Balrampur district 7.17 mbgl (2016) was the highest level of ground water while lowest depth of ground water level was 3.03 mbgl (1994). Significantly increasing trend of ground water level was observed in Mann-Kendall test method whereas in linear trend graph method there was increase of ground water level but it was non-significant table 3. Surajpur district maximum ground water level was 7.75 mbgl (2010) and minimum level was 5.12 mbgl (1998). The trend of annual ground water was significantly increased when data was analysis through Mann-Kendall method. Koria district maximum depth of ground water level was 5.85 mbgl (1996) and minimum was 2.86 mbgl (1994). The outcome of analysis of annual ground water level in linear trend graph method indicates significantly increasing trend.

Similar results were also reported by Kumar *et al.*, (2018) [6] according to him the rising trends indicate an increasing depth of water level from ground surface and declining trend indicates the decreasing depth of water level from the ground surface. The groundwater table is declining in these locations due to over extraction of groundwater and might be due to no recharge plan in respective districts. Ribeiro *et al.*, (2015) [8] showed that the significant downward trends at the majority of the wells. Yilmaz *et al*. (2020) [16] Mann-Kendall test was used for trend analysis. Significant decreasing trends were observed in depth of all most all well in Sharjah, which indicated decreasing groundwater levels. The best known non-parametric test is based on the Mann-Kendall's test and has been used by various researchers to understand long-term trends in groundwater levels (Tabari *et al.*, 2011; Vousoughi *et al.*, 2013; Machiwal and Jha, 2014; Ribeiro *et al.*, 2014) [12, 15, 7, 9].

Seasonal trend analysis of Groundwater depth

Long term 27 years (1993-2019) groundwater level data of Baster plateau and Northern hill zone of Chhattisgarh is presented in Table-4. Bastar district recorded in non-mosoon, pre-monsoon, monsoon and post-monsoon seasons there was non-significant decreasing trend of ground water level was found in Mann-Kendall test method. Dantewada district was reported in Mann-Kendall method analysis indicates that pre-monsoon, monsoon and post monsoon is significant decreasing but non-monsoon season non-significant decreasing. Narayanpur district outcome of Mann-Kendall method analysis indicates that there was significantly decreasing trend of ground water level during monsoon and post-monsoon season whereas non-monsoon non-significant increasing but pre-monsoon season non-significant decreasing. Sukma district recorded in Seasonal analysis carried out by Mann-Kendall test method reported significantly decreasing trend of ground water level during three seasons. While in linear trend graph method the results was non-significant during all four season. Bijapur district of ground water level was significantly increasing during non-monsoon season in Mann-Kendall test method; whereas in during pre-monsoon, monsoon post-monsoon season it was increase but non-significantly. Kondagaon district recorded in Mann-Kendall test method, during non-monsoon season significantly increasing trend was observed and three season non-significant. Jashpur district during non-monsoon and pre-monsoon season the ground water level was significantly increasing whereas monsoon and post-monsoon non-significantly increasing in Mann-Kendall test method. Surguja district during non-monsoon season, monsoon season and post-monsoon season significantly increasing but pre-monsoon season non-significant trend was recorded under Mann-Kendall test method. Balrampur district recorded in Mann-Kendall test method was three season significantly increasing but monsoon season non-significantly increasing. Surajpur district was non-monsoon and post-monsoon season reported significantly increasing trend of ground water level in Mann-Kendall test method. Koria district was non-significant in ground water level under Mann-Kendall test method during all the season.

Biswas *et al.*, (2018) [5] workout trend analysis of groundwater level for pre-monsoon and post-monsoon season of Agra. The results showed significant declined in the groundwater levels. Abdullahi *et al.* (2015) [1] analyzed the ground water data collected from the seven hydrological stations in Terengganu, Malaysia and resulted that there was an expectation of increases in trend in the future in the area. Thakur and Thomas (2011) [13] studied the seasonal groundwater levels trends for few blocks of Sagar district. The non-parametric Mann-Kendal rank correlation test as well as the parametric linear regression test has used for trend detection. Patele *et al.* (2015) interposed through analysis of groundwater level which helps in detecting trend, its behaviour and identifying the causes of water level decline. It can be used for effective planning of management strategies for development and utilization of groundwater resources in a region. Brocque *et al.* (2018) and Asoka *et al.* (2017) study proposed that depletion of groundwater is because of irrigation purposes in high crop intensity and high-water demanding crop areas while Chinnasamy and Agoramoorthy (2015) reports suggested that groundwater is extremely dependent on rainfall and decreasing rainfall leads to depletion of groundwater. Agarwal *et al.* (2017) [2] results indicated that about 49%, 53% and 58% wells showed downward trends in the pre-monsoon season and about 11%, 13% and 16% wells showed upward trends at 1%, 5% and 10% significance level, respectively.

Table 1: Annual Groundwater depth (mbgl) of six districts (Bastar, Dantewada, Narayanpur, Sukma, Bijapur, Kondagaon) of Baster plateau zone from 1993 to 2019.

District	Bastar	Dantewada	Nararayanpur	Sukma	Bijapur	Kondagaon
Year	GW (mbgl)	GW (mbgl)	GW (mbgl)	GW (mbgl)	GW (mbgl)	GW (mbgl)
1993	4.49	4.59	2.95	6.86	4.60	4.97
1994	5.01	3.96	2.79	5.92	3.85	4.30
1995	3.80	3.93	2.21	5.62	3.62	4.04
1996	4.19	3.78	2.72	5.88	3.86	4.89
1997	4.97	4.19	3.00	6.00	5.18	5.07
1998	3.90	3.57	2.69	5.77	4.05	4.90
1999	3.69	3.33	2.38	4.92	4.08	4.81
2000	4.01	4.31	2.42	5.23	5.19	5.33
2001	4.57	3.96	2.59	6.02	4.88	5.13
2002	5.21	4.60	2.86	5.82	5.80	5.12
2003	5.32	4.81	3.19	5.41	5.98	5.90
2004	3.77	3.27	2.41	5.34	NA	3.70
2005	4.06	3.41	2.21	6.67	NA	4.37
2006	3.54	3.44	2.62	5.99	NA	4.01
2007	3.61	3.25	NA	6.87	NA	4.67
2008	4.33	3.47	2.50	5.38	NA	4.59
2009	3.94	3.93	NA	6.68	NA	5.13
2010	5.75	3.54	NA	6.83	NA	4.40
2011	4.25	NA	NA	7.85	NA	5.47

2012	3.70	NA	NA	6.57	NA	4.90
2013	4.81	NA	NA	7.00	NA	5.22
2014	3.53	NA	NA	7.12	NA	4.59
2015	3.63	5.85	1.96	9.80	NA	5.47
2016	4.19	6.83	3.81	6.87	NA	5.28
2017	4.96	6.08	NA	6.03	NA	5.23
2018	3.78	NA	NA	6.60	NA	5.49
2019	3.93	6.46	NA	NA	NA	4.92

Table 2: Annual Groundwater depths (mbgl) of five districts (Jashpur, Surguja, Koria, Surajpur and Balrampur of Northern hill zone from 1993 to 2019.

District	Jashpur	Surguja	Balrampur	Surajpur	Koria
Year	GW (mbgl)	GW (mbgl)	GW (mbgl)	GW (mbgl)	GW (mbgl)
1993	4.34	5.98	8.36	6.89	5.52
1994	4.30	3.10	3.03	3.91	2.86
1995	4.22	4.03	3.32	5.18	3.48
1996	4.10	6.23	4.95	6.34	5.85
1997	4.48	6.16	5.21	6.72	5.43
1998	3.58	4.82	3.98	5.12	3.46
1999	3.42	4.57	5.00	5.28	4.09
2000	4.85	6.43	5.11	6.16	4.77
2001	4.29	5.35	4.99	5.47	4.81
2002	4.54	6.11	5.26	6.38	5.85
2003	4.41	4.97	4.89	6.25	4.49
2004	4.09	5.18	5.29	6.00	4.77
2005	4.86	6.05	6.30	6.88	5.06
2006	4.72	5.99	5.77	6.78	4.91
2007	4.62	6.01	6.03	7.40	4.55
2008	4.59	5.30	5.76	6.68	4.87
2009	5.01	6.11	6.63	7.25	5.27
2010	4.91	6.28	6.97	7.75	5.42
2011	5.50	5.95	6.65	6.96	4.55
2012	4.16	5.39	6.13	6.04	3.78
2013	4.74	6.00	5.96	6.39	5.20
2014	4.38	6.24	7.17	6.52	4.69
2015	5.47	6.35	6.35	6.38	5.63
2016	5.67	6.94	7.17	6.92	5.48
2017	5.24	6.33	6.89	6.26	4.86
2018	5.19	6.52	6.41	6.44	4.69
2019	4.98	6.25	6.92	6.12	4.92

Table 3: Mann-Kendall Trend analysis of Annual Groundwater for 11 districts of Bastar plateau and Northern hill zone of Chhattisgarh from 1993-2019.

S.N.	District	Year	Mann-Kendall Trend Results	Linear trend Results
1	Bastar	1993-2019	NS Dec	NS Dec
2	Dantewada	1993-2019	NS Dec	NS Dec
3	Narayanpur	1993-2019	NS Dec	NS Dec
4	Sukma	1993-2019	S Inc.*	S Inc*
5	Bijapur	1993-2019	S Inc*	NS Inc
6	Kondagaon	1999-2019	S Inc***	S Inc*
7	Jashpur	1993-2019	S Inc*	S Inc*
8	Surguja	1993-2019	S Inc*	S Inc*
9	Balrampur	2003-2019	S Inc*	NS Inc
10	Surajpur	1993-2019	S Inc***	NS Inc
11	Koria	1993-2019	NS Inc	S Inc*

[NS (non-significant), S (significant), Dec (decreasing), Inc. (increasing), * = 1% significant level, ** = 5% significant level and *** = 10% significant level for Mann-Kendal trend.]

Table 4: Mann-Kendal Trend analysis of seasonal Groundwater depth of 11 districts of Bastar Plateau and Northern hill zone of Chhattisgarh from 1993-2019.

			Mann-Kendall Trend results			
S.N.	District	Year	Non-Monsoon	Pre-Monsoon	Monsoon	post-Monsoon
1	Bastar	1993-2019	NS Dec	NS Dec	NS Dec	NS Dec
2	Dantewada	1993-2019	NS Dec	S Dec	S Dec	S Dec*
3	Narayanpur	1993-2005	NS Inc	NS Dec	S Dec**	S Dec**
4	Sukma	1993-2019	S Inc*	S Dec**	S Dec*	S Dec**
5	Bijapur	1993-2003	S Inc*	NS Inc	NS Inc	NS Inc

6	Kondagaon	1999-2019	S Inc**	NS Dec	NS Inc	NS Inc
7	Jashpur	1993-2019	S Inc**	S Inc*	NS Inc	NS Inc
8	Surguja	1993-2019	S Inc***	NS Inc	S Inc**	S Inc*
9	Balrampur	2003-2019	S Inc	S Inc	NS Inc	S Inc
10	Surajpur	1993-2019	S Inc*	NS Inc	NS lnc	S Inc***
11	Koria	1993-2019	NS Inc	NS Inc	NS Dec	NS Inc

[NS (non-significant), S (significant), Dec (decreasing), Inc. (increasing), * = 1% significant level, ** = 5% significant level and *** = 10% significant level for Mann-Kendal trend.]

Conclusion

Most of the districts of Bastar plateau and Northern hill zone of different districts the groundwater level are falling down non-significantly whereas in seven districts they are Sukma, Bijapur, Kondagaon, Jashpur, Surguja, Balrampur and Surajpur the ground water level was increasing significantly which required immediate attention.

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