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Trend analysis of ground water quality: A case study of Eastern Uttar Pradesh

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Abstract
Uttar Pradesh is a water stressed state due to limited precipitation. Moreover, the Utter Pradesh of water supplies is under extra stress due to the country's rapid population growth and rises in industrial and agricultural activity. Various Ground Water Quality parameters data likes pH, electrical conductivity (EC), Total Dissolved Solid (TDS), Total Hardness (TH) and Calcium. This study employs a Ground Water Quality data to identify trends and patterns of Ground Water Quality in the 27 districts of Uttar Pradesh, such as- Prayagraj, Azamgarh, Bahraich, Ballia, Basti, Mirzapur, Pratapgarh, Gonda, Sultanpur, Jaunpur, Ghazipur, Varanasi, Chandauli, Ayodhya, Gorakhpur, Deoria, Shrawasti, Balarampur, Sidharth Nagar, Sant Kabir Nagar, Maharajganj, Kushinagar, Mau, Sonbhadra, Sant Ravidas Nagar, Ambedkar Nagar and Barabanki. Trend analysis of groundwater levels is an essential component of groundwater management, ground water level and five hydro-geochemical elements at 27 districts located of Uttar Pradesh. This study focuses on two prominent methods for trend analysis: the Mann-Kendal test and the Sen's slope estimator. The methodology of trend analysis is based on graphical exploratory analysis; this is further verified by a statistical test. Mann-Kendal test was performed for trend analysis using R studio software. Sen's estimator was used to calculate the magnitudes of the trends. Mann-Kendall non-parametric test was used for the temporal trend analysis. Since it provides significant increasing or decreasing information about the ground water trend.

Keywords: Ground water quality parameters, trend analysis, Mann-Kendal test, Sen's slope

1. Introduction
Ground water is a source of drinking, agriculture and industrial water demand. To evaluate the quality of ground water, it is crucial for human health and drinking purpose. Some regions use groundwater resources, such as desalinated water, to meet their water needs. Due to the rapid growth of human needs in many sectors, groundwater resources are always subjected to significant challenges accommodated by pollution and health hazard risks. Understanding of the factors governing variation and detection of groundwater quality trends in these regions are essential for providing an early warning system for quality changes where protection and sound management of the resource can be efficiently set. For a more cogent assessment of the status and trends of site groundwater properties, joint modeling of both spatial and time variables in a single spatio-temporal modeling becomes essential. The choice of a statistical trend analysis approach and its ability to correctly identify a monotonic trend are influenced by groundwater quality data.
Trend analysis is providing to significant and insignificant information about the direction of ground water quality parameters trend. Mann-Kendall and Sen's Slope tests is use to detect ground water quality parameter trends and magnitude of trend of water quality parameters.
In this study, Mann-Kendall trend test has been used to determine the trends in the data on ground water quality as well as the sources of the variations that are causing the pollution issue. Thus, this method is highly suitable to be applied in detecting trends of skewed hydrologic time series containing outliers. Though some hydrological series exhibit strong serial correlation, the MK test for trend detection relies on the sample data's assumed serial independence because of its flexibility, non-parametric statistical tests can deal with oddities in the data, such as missing

values, censored data, seasonality, and highly skewed data. In this study 27 stations were selected for the analysis of Mann Kendall test and Sen's slope estimator.

2. Materials and Methods

2.1 Study Area

Uttar Pradesh is northern State of India its coordinates vary between 23˚52'N to 31˚28'N latitudes and 77˚3'E to 84˚39'E Longitudes. In this study, 27 districts from Eastern U.P. were selected for study.

The study area's details are shown in Table 1, which includes the districts' names, latitude (N), longitude (E), elevation (m), and area (hac). Geographical information of 27 districts of Uttar Pradesh is presented in Fig.1.

Table 1: List of districts

Sr. No.	Districts	Latitude (N)	Longitude (E)	Elevation(m)	Area (hac.)
1	Prayagraj	25.43	81.84	98	5177
2	Ambedkar Nagar	26.40	82.39	133	2334
3	Azamgarh	26.07	83.18	64	3909
4	Bahraich	27.57	81.59	126	3712
5	Ballia	25.75	84.14	69	3012
6	Balarampur	27.42	82.17	106	3382
7	Barabanki	26.93	81.18	100	4463
8	Basti	26.82	82.76	77	2528
9	Chandauli	25.26	83.26	70	2542
10	Deoria	26.5	83.78	68	2561
11	Ayodhya	26.77	82.15	97	2110
12	Ghazipur	25.58	83.57	67.5	3393
13	Gonda	27.13	81.96	120	4029
14	Gorakhpur	26.76	83.36	75	3074
15	Jaunpur	25.74	82.69	82	4052
16	Kushinagar	26.73	83.88	81	2892
17	Maharajganj	27.14	83.56	200	3194
18	Mau	25.94	83.55	63	2071
19	Mirzapur	25.13	82.56	80	4536
20	Pratapgarh	25.89	81.94	491	3738
21	Santravidas Nagar	25.32	82.43	85	1331
22	Sant Kabir Nagar	20.00	73.75	81	1014
23	Shrawasti	27.50	82.03	112	3170
24	Sidharth Nagar	27.27	82.82	88	3490
25	Sonbhadra	24.68	83.06	330	6811
26	Sultanpur	26.26	82.07	95	4443
27	Varanasi	25.32	82.98	81	1556

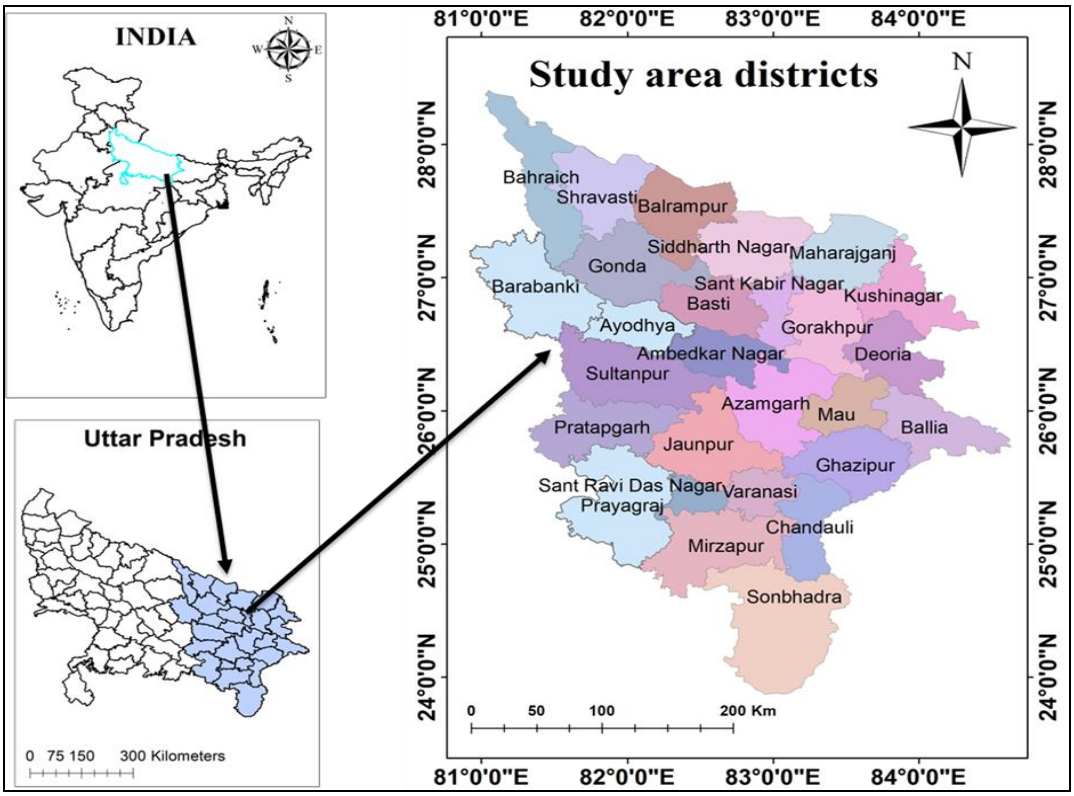


Fig 1: Graphical representation of 27 districts of Uttar Pradesh

2.1.1 Ground Water Quality Data

A trend study of ground water quality parameters was conducted using data on several parameters that were gathered over an 18-year period from 27 districts in Uttar Pradesh. This study is based on Ground water quality data in 27 districts of Uttar Pradesh, which is acquired from the CENTRAL GROUND WATER BOARD (CGWB). Headquarter of CGWB is established in Faridabad in 1970. In this study used 5 Ground water quality parameters, in which electrical conductivity (EC) is only one parameter is physical parameter and pH, total dissolved solids (TDS), total hardness (TH) and calcium are chemical parameters.

2.2 Methodology

In this study, Inverse distance weighted (IDW) was employed to analyze the geographical and temporal trends in ground water levels. It is made up of several graphical, parametric and non-parametric statistical methods that are separate into exploratory and confirmatory data analysis. Since the ground water level data is typically non- normally distributed, the temporal trend analysis was conducted using the MK non-parametric test. Trend analysis helps us identify whether a groundwater quality variable's measured values have increased or decreased during the time period.

2.2.1 Mann-Kendall Test

The Mann Kendal (MK) is a non- parametric rank- based test and used in several ground water trend analysis studies. MK test is proposed by Mann (1945) [22]. The Z-statistical for this test can be calculated by:

$$\text{Sign } (x_i - x_j) = \begin{cases} 1 & if\ x_i - x_j > 0 \\ 0 & if\ x_i - x_j = 0 \\ -1 & if\ x_i - x_j < 0 \end{cases} \quad ...1$$

Where:
x = data set
i = 1, 2, 3, …..n term
j = i+1

For calculating the sum of all sign formula will be used –

$$S = \sum_{i=1}^{n-1} \cdot \sum_{j=i+1}^{n} sing\ (x_i - x_j) \quad ...2$$

The following formula used to calculate the variance –

$$var\ (S) = \frac{n\,(n-1)(2n+5) - \sum_{p-1}^{q} .tp\,(tp-1)(2tp+5)}{18} \quad ...3$$

Where:
Var(s) = variance of sum
N = total number
tp = number of terns whose equal value
For calculating the trend value z value z will be calculate by following formula-

$$Z = \begin{cases} \frac{s-1}{\sqrt{var\ (s)}} & if\ S > 0 \\ 0 & if\ S = 0 \\ \frac{s+1}{\sqrt{var\ (s)}} & if\ S < 0 \end{cases} \quad ...4$$

Where:
Z = Mann- Kendall statistics
Positive z value shows the positive trend and negative z value show the negative trend.

2.2.2 Sen's slope Estimator

If a time series has a linear trend, a straight forward non-parametric method created by Sen's (1968) [23] can be used to estimate the true slope (change per unit time). The slope estimates of *N* pairs of data are first computed by:

$$Q_i = \frac{x_j - x_k}{j - k} \text{ For } i = 1, ..., N \quad ...5$$

Where
X_j = data values at time j
X_k = data values at time k (j>k)
Q_i = the Sen's estimator of slope.

2.2.3 Change point detection

A non-parametric change detection method called the Pettitt (1979) approach was developed to determine the most likely year of change for a ground water quality time series pattern. It can determine when the mean of the time series changes and when those changes first manifested themselves (Jhajharia, 2021) [3].
Statistics from the nonparametric test an explanation of Ut for this test would be as follows:

$$U_t = \sum_{j=1}^{t} \sum_{j=t+1}^{n} sign(x_t - y_j) \quad ...6$$

$$\left(sign(x_i - x_j)\right)^{\cdot} = \begin{cases} 1 \ldots\ldots\ldots \text{if} > 0 \\ 0 \ldots\ldots\ldots \text{if} = 0 \\ 1 \ldots\ldots\ldots \text{if} < 0 \end{cases} \quad ...7$$

The confidence level (ρ) and test statistic K for the sample length (n) can be explained as follows:

$$K = \max(Ut) \quad ...8$$

$$\rho = exp\left[\frac{-k}{n^2 + n^s}\right] \quad ...9$$

The null hypothesis is rejected when ρ is less than the particular confidence level. The definition of the approximate significance probability (p) for a change-point is provided below:

$$P = 1 - \rho \quad ...10$$

3. Results and Discussion

3.1 Box plot

The variability of values in a dataset can be quickly and visually summarized with box charts. These display the dataset's median,

upper and lower quartiles, lowest and maximum values, and any outliers. Errors or anomalous events in data can be exposed by outliers. A box plot is created when the data distribution is standardized and presented using the following five summary variables: minimum, median, Q1 (first quartile), Q3 (third quartile), and maximum. The first quartile to the third quartile is where we draw a box in a box plot. Through the box at the median is a vertical line. Whiskers are arranged from the least or maximum to each quartile.

Box plot performed on the raw data set of groundwater quality data set of the study region comprised of 5 parameters further from 27 district of Uttar Pradesh. Stepping backwards According to box plot, the space-based distinguishing characteristics include pH, EC, TDS, TH and Calcium. Box plot predicted important differences in water composition from ground water quality.

Fig.2 represents of calcium box plot, its show the visibility of calcium variation in 27 districts. Calcium is a major positive ion in natural fresh water. Its concentration in groundwater it ranges from 1 mg/L to less than 500 mg/L. Maharajganj shows the maximum value of Calcium in compared to other districts and minimum value of Calcium shows in Mau. Ayodhya and Chandauli do not show variation of the Calcium value. Remaining districts represent the variations in different amount of calcium value.

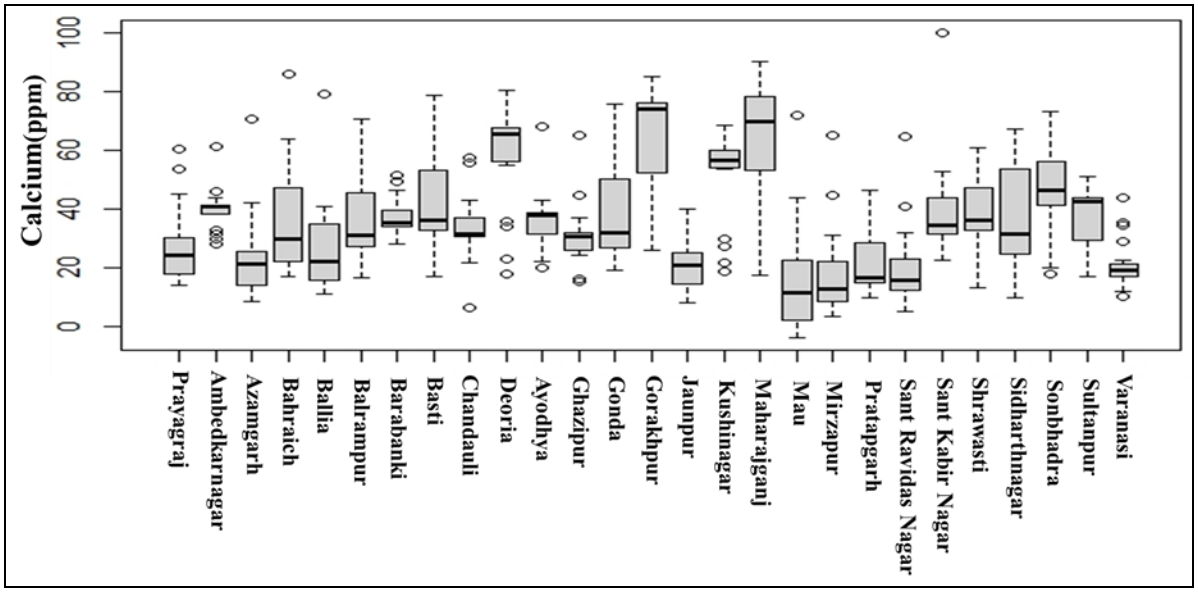


Fig 2: Representation of Box plot of Calcium

Fig.3 represents of Electrical Conductivity (EC) box plot, its shows the visibility of EC variation in 27 districts. The electrical conductivity of fresh groundwater is typically less than150 µS/cm. Pratapgarh shows the maximum value of Electrical Conductivity (EC) compared to other districts and minimum value of Electrical Conductivity show in Varanasi. Ghazipur and Gonda district represent the same median of EC, Mau and Mirzapur also same median. Ballia and Balrampur do not show variation in maximum value while minimum value shows the variation. Remaining districts represent the variations in different amount of Electrical Conductivity value.

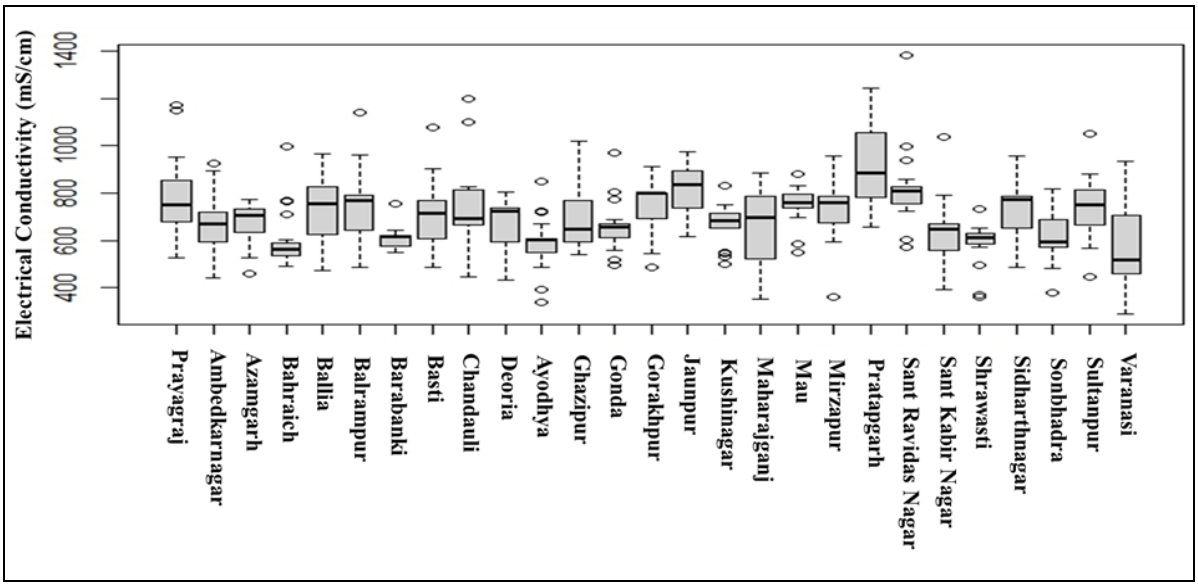


Fig 3: Representation of box plot of Electrical Conductivity (EC)

Fig.4 represents of pH box plot, its show the visibility of pH variation in 27 districts. The pH of groundwater typically ranges

from about 6.0 to 8.5. Kushinagar, Mau, Maharajganj and Pratapgarh do not show variation in maximum value while minimum value shows the variation. Mirzapur show the maximum value of pH compared to other districts and minimum value of pH show in Barabanki districts. Remains districts represent the variations in different amount of pH value.

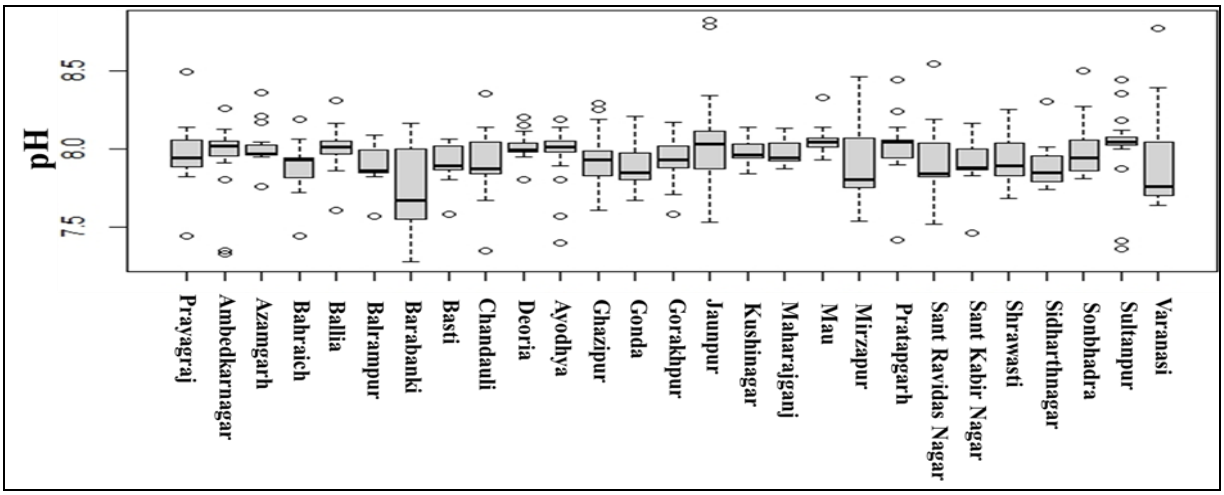


Fig 4: Representation of box plot of pH

Fig.4 represents the box plot of Total dissolved solids, its show the visibility of TDS variation in 27 districts. According to WHO specification TDS up to 500 mg/l is the highest desirable and up to 1,500 mg/l is maximum permissible. Shrawasti shows the maximum value of Total Dissolved Solids (TDS) compared to other districts and minimum value of TDS show in the Ambedkar Nagar. Remains districts represent the variations in different amount of Total Dissolved Solids value.

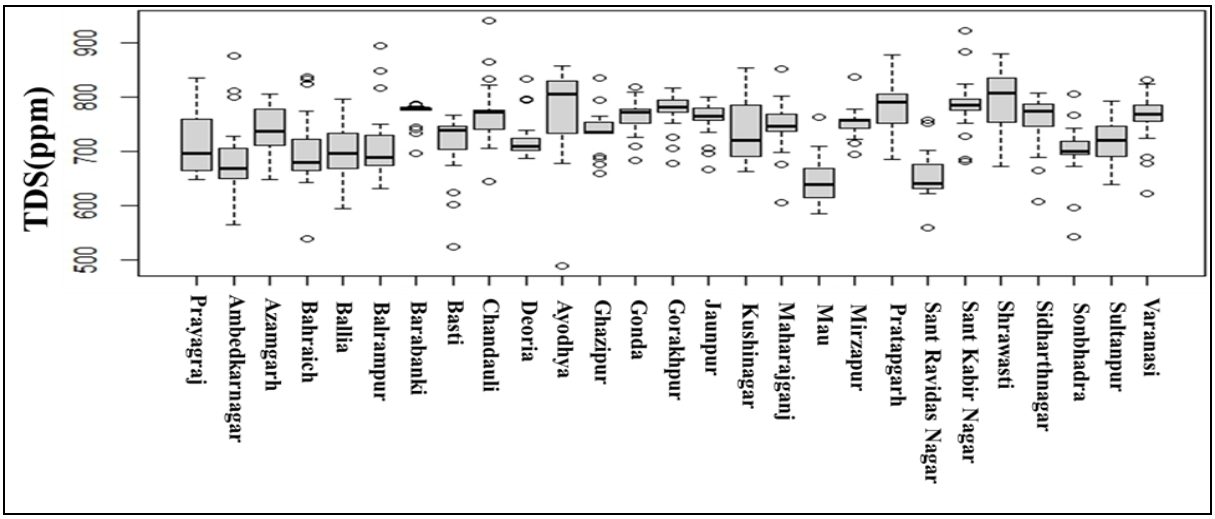


Fig 5: Representation of box plot of TDS

Fig. 6 represents the box plot of Total Hardness, its shows the visibility of Total Hardness (TH) variation in 27 districts. Maximum permissible limit of Total Hardness is 600 mg/l. Jaunpur show the maximum value of TH compared to other districts and minimum value of TH show in Maharajganj. Azamgarh and Ballia district show same median of TH. Remains districts represent the variations in different amount of Total Hardness value.

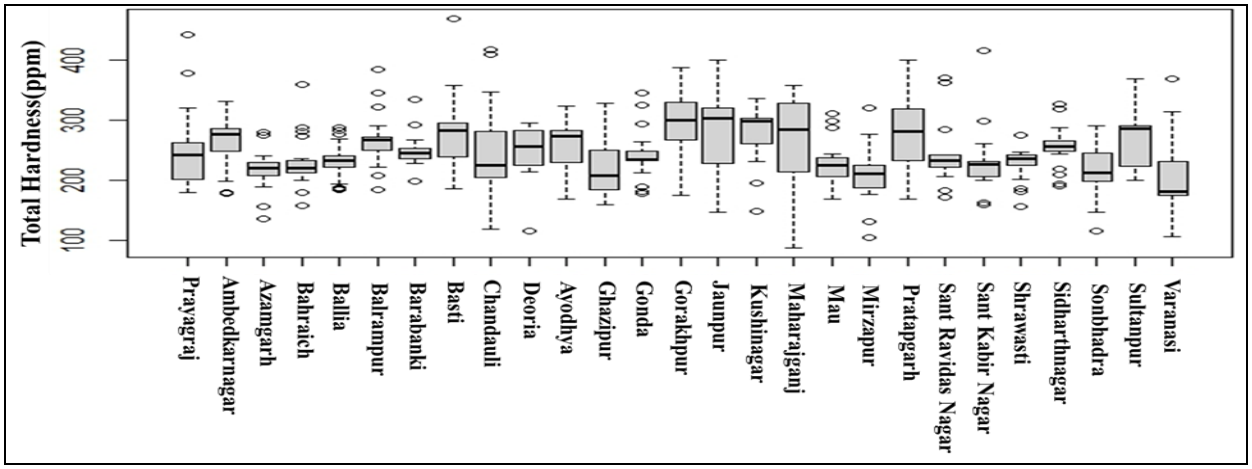


Fig 6: Representation of box plot of Total Hardness (TH)

3.2 Spatial variation of ground water quality parameters

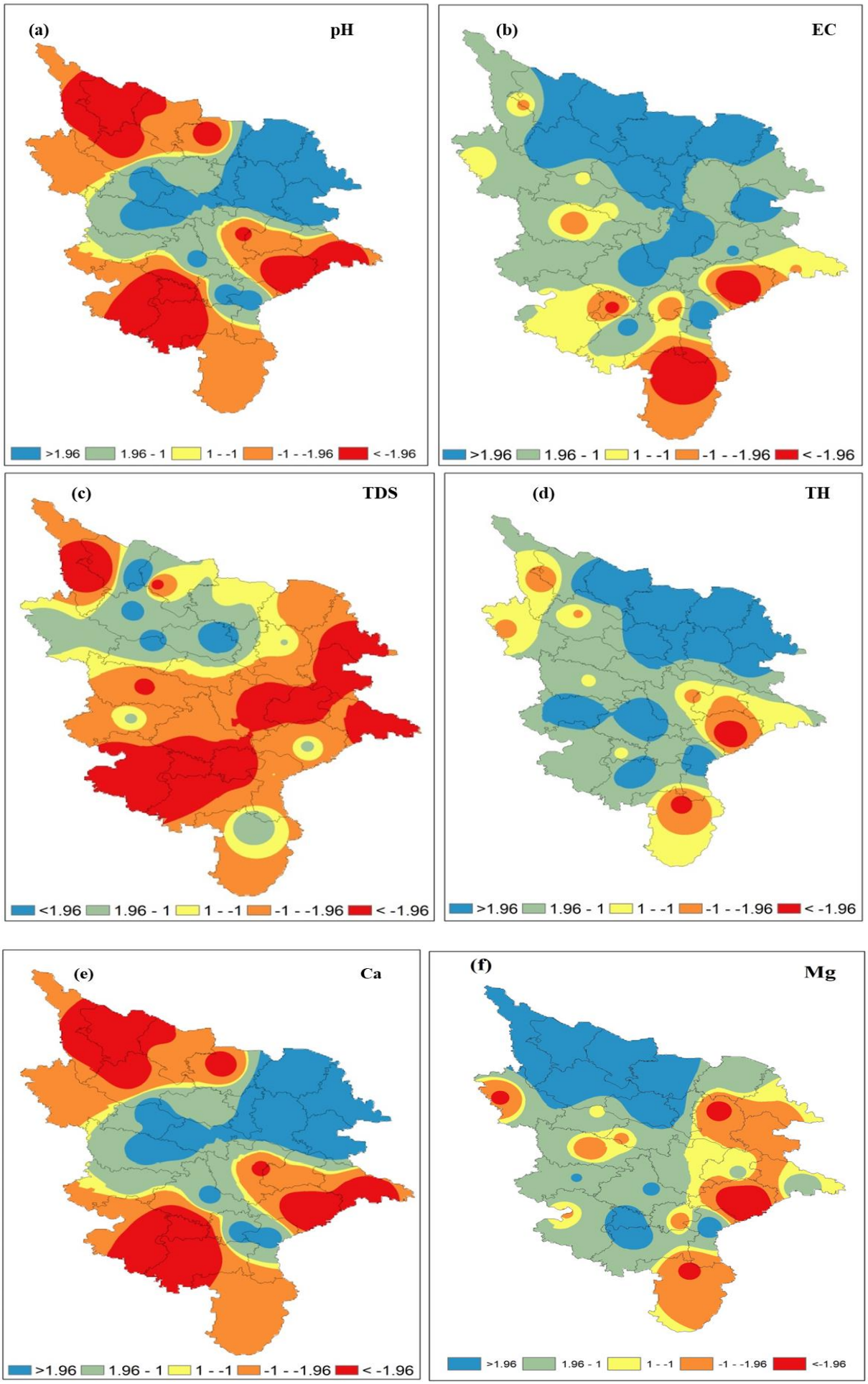
Understanding groundwater quality is crucial because it is the key determinant of whether it is suitable for drinking. Maps of the ground water quality were plotted for each parameter in 27 districts of Uttar Pradesh. Geographical information systems (GIS) software was utilized to create spatial maps of groundwater quality across the 27 districts of Uttar Pradesh. GIS allows for the visualization of data in the form of maps, enabling the identification of spatial patterns and trends. Spatial variation of groundwater quality parameters shows variations within and between districts. Results of the spatial analysis and discuss the spatial variation of ground water quality across the 27 districts of Uttar Pradesh. Areas of high and low groundwater quality were identified hotspots of contamination, and potential sources of pollution.

The spatial distribution of groundwater quality parameter data was performed by the IDW (Inverse Distance Weighted) interpolation technique for ten parameters of groundwater quality, such as pH, Electrical Conductivity (EC), Total Dissolved Solids (TDS), Total Hardness (TH), Calcium (Ca), Magnesium (Mg), Sodium (Na), Potassium (K), Carbonate, and Bicarbonate, respectively. Where blue color represents the significant increasing Z statistics value and red color represents the decreasing Z statistics value of groundwater quality parameters in Fig. 7.

The spatial variation of the ground water quality parameters (pH, EC, TDS, TH, Ca, Mg, Na, K, carbonate, and bicarbonate) is shown in Fig. 7. This Fig. shows the significant increasing trends were found in Sultanpur to Kushinagar and the significant decreasing trend found in Shrawasti, Mirzapur, and Ballia. The non-significant increasing or decreasing trend is seen in the remaining districts (Fig. 7.a). Districts from Gonda to Maharajganj including Jaunpur and Azamgarh, the EC show a significant increasing trend (Fig. 7b). Sonbhadra and Ghazipur represent a significant decreasing trend. Other districts represent a non-significant increasing or decreasing trend. Fig. 7c represents the maximum significant decreasing trend of TDS in 8 districts, and only 4 districts show a minimum significant increasing trend, such as Shrawasti, Ayodhya, Gonda, and Basti. The remaining districts show a non-significant increasing or decreasing trend. In Fig. 7d, there is a significant increasing trend of TH from Shrawasti to Ballia which also includes 4 districts (Pratapgarh, Jaunpur, Mirzapur, and Chandauli). Only two districts (Ghazipur and Sonbhadra) show a significant decreasing trend, and the other remaining districts show an insignificant increasing or decreasing trend.

The significant increasing trend of Ca is represented by Fig. 7(e), which shows the various districts from Sultanpur to Kushinagar. Nine districts—Bahraich, Shrawasti, Gonda, Balrampur, Mirzapur, Sant Ravidas Nagar, Prayagraj, Ballia, and Ghazipur—show a significant decreasing trend. Bahraich, Shrawasti, Balarampur, Gonda, Sidharth Nagar, and Basti are the six districts where magnesium levels are significantly rising, while Ghazipur, Gorakhpur, and Barabanki are the districts where magnesium levels are significantly falling. Additionally, several left-hand districts display the marginally significant upward or downward trend in Fig. 7f. Na is significantly increasing in Shrawasti, Balarampur, Gonda, Siddharth Nagar, Sant Kabir Nagar, Basti, and Maharajganj, as seen in Fig. 7g. The seven districts (Sonbhadra, Mirzapur, Chandauli, Ghazipur, Varanasi, Sant Ravi das Nagar, and Jaunpur) in the same Fig. 7g show a significant decreasing tendency. The remaining districts exhibit a negligible trend of either increasing or decreasing Na. Potassium (K) in Fig. 7h indicates a significant decreasing trend in Sonbhadra, Mirzapur, Chandauli, Ghazipur, Varanasi, Sant Ravi das Nagar, and Jaunpur and a significant increasing trend in Shrawasti, Balarampur, Gonda, and Siddharth Nagar.

The marginally increasing or decreasing pattern is evident in other districts. Twelve districts (Maharajganj, Ballia, Mau, Azamgarh, Ambedkar Nagar, Sultanpur, Sonbhadra, Mirzapur, Varanasi, Prayagraj, Sant Ravidas Nagar, and Jaunpur)—roughly 45% of the area covered in Fig. 7.1i—show a notable increasing trend in carbonate. The districts of Chandauli, Ghazipur, Siddharth Nagar, and Shrawasti exhibit a significant decrease in trend, while the remaining districts show a negligible increase or decrease in trend. The bicarbonate trend is significantly declining in twelve districts (Bahraich, Shrawasti, Barabanki, Sant Ravidas Nagar, Sonbhadra, Ghazipur, Ballia, Mau, Azamgarh, Siddharth Nagar, Sant Kabir Nagar, and Basti), which account for almost 45% of the area covered by Fig. 7j. The districts depicted in Fig. 1j are Chandauli, Mirzapur, Jaunpur, Deoria, Kushinagar, Maharajganj, and Gorakhpur; the remaining districts display either a small increase or decrease in trend.


(a)
pH
>1.96
1.96 - 1
1 - -1
-1 - -1.96
< -1.96
(b)
EC
>1.96
1.96 - 1
1 - -1
-1 - -1.96
< -1.96
(c)
TDS
<1.96
1.96 - 1
1 - -1
-1 - -1.96
< -1.96
(d)
TH
>1.96
1.96 - 1
1 - -1
-1 - -1.96
< -1.96
(e)
Ca
>1.96
1.96 - 1
1 - -1
-1 - -1.96
< -1.96
(f)
Mg
>1.96
1.96 - 1
1 - -1
-1 - -1.96
<-1.96

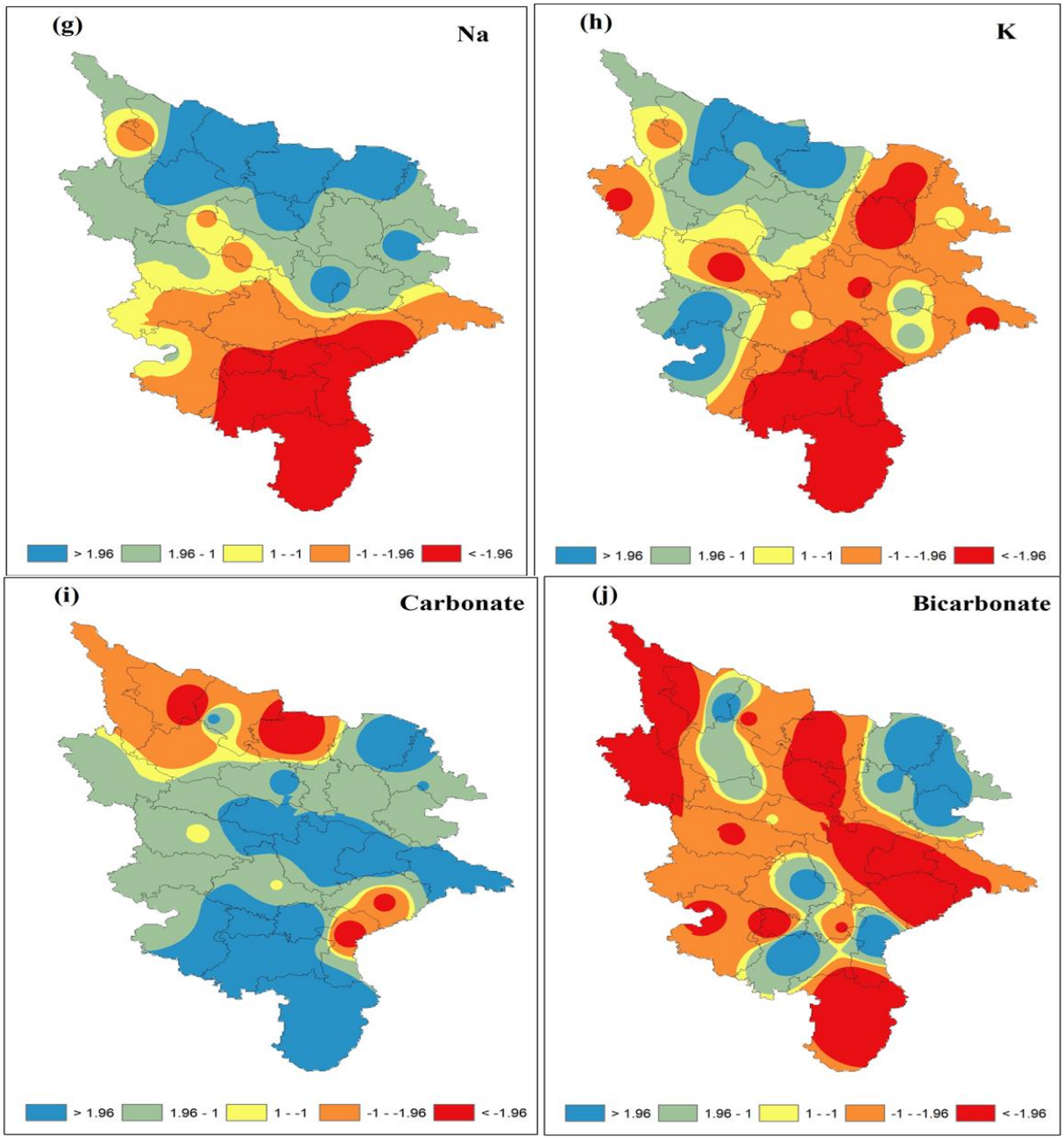


Fig 7: Graphical representation of spatial variation of (a) pH, (b) EC (c) TDS, (d) TH, (e) Ca, (f) Mg, (g) Na, (h) k, (i) Carbonate and (j) Bicarbonate.

3.3 Heat Map

Heat map for groundwater quality parameters across 27 districts of Uttar Pradesh based on 10 parameters were prepared total 10 parameters (pH, EC, TDS, TH, Ca, Mg, Sodium, Potassium, Carbonate, and Bicarbonate) for each of Uttar Pradesh's 27 districts were selected. Heat map was generated using MS Excel, where each district is shaded according to the average value of each ground water quality parameter. Heat map focuses on regions where particular parameter values are high or low. Heat map of groundwater quality for 10 parameters across the 27 districts of Uttar Pradesh, provided valuable insights into spatial variations and potential areas of concern for groundwater management and environmental protection.

Heat map represents the variation of Z statistics according to time series as shown. In Fig. 8, Red colors represent a significant decreasing trend of groundwater quality parameters (pH, EC, TDS, TH, Ca, Mg, Sodium, Potassium, Carbonate, and Bicarbonate), and blue colors represent a significant increasing trend. pH and Ca represent a significantly increasing trend in Shrawasti and Sant Ravidas Nagar districts, as well as a significant increasing trend in Bahraich district. EC, TDS, and TH represent a significantly decreasing trend in Shrawasti, Chandauli, Jaunpur, Mirzapur, Basti, and Azamgarh. The remaining districts in Fig. 8 show an insignificant increasing or decreasing trend in these five parameters.

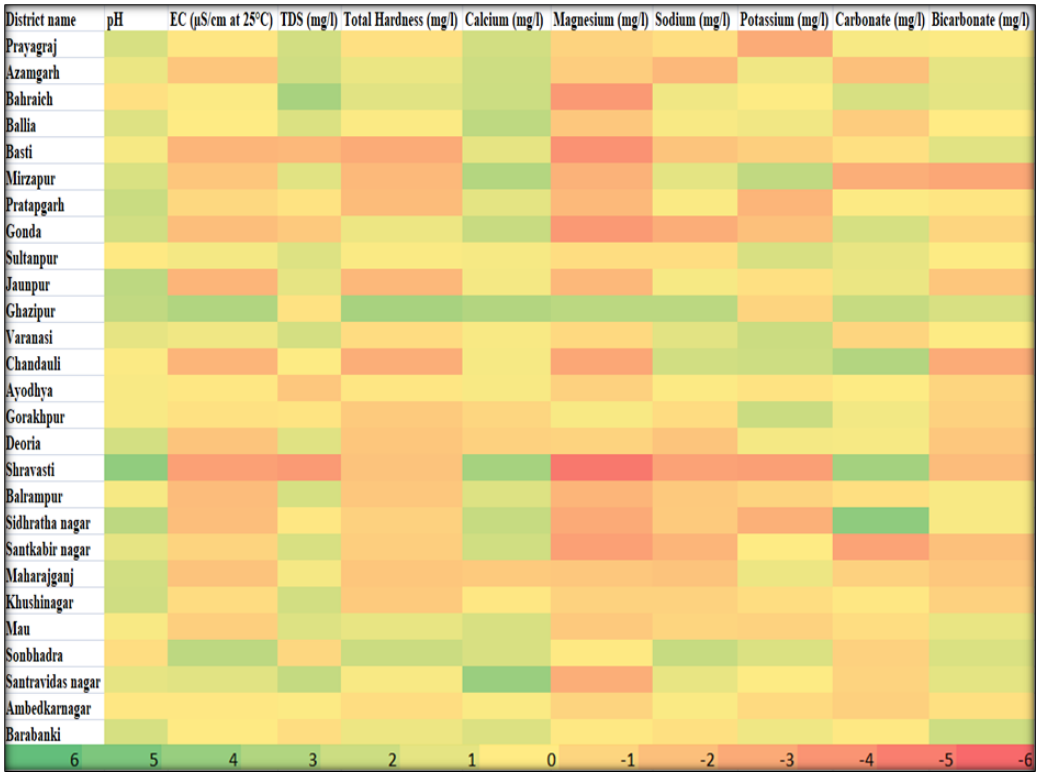


Fig 8: Heat map of 27 districts in Uttar Pradesh

Table 2: Sen's slope result of ground water quality parameters in 27 districts of U.P.

S. No.	District name	pH	EC (µS/cm at 25 °C)	TDS (mg/l)	Total Hardness (mg/l)	Calcium (mg/l)
1	Prayagraj	0.01	-0.50	5.23	-0.98	0.81
2	Azamgarh	0.00	-7.21	3.13	0.35	0.87
3	Bahraich	0.00	0.05	6.05	1.28	1.72
4	Ballia	0.01	-2.81	3.96	-0.08	0.99
5	Basti	0.00	-12.87	-2.90	-4.04	0.55
6	Mirzapur	0.02	-7.45	0.61	-2.70	0.98
7	Pratapgarh	0.01	-11.82	-1.89	-5.33	0.63
8	Gonda	0.01	-3.65	-1.56	0.23	1.45
9	Sultanpur	0.00	0.90	1.77	0.02	0.03
10	Jaunpur	0.02	-13.21	1.65	-6.67	0.12
11	Ghazipur	0.01	15.29	-0.47	5.99	0.69
12	Varanasi	0.01	2.03	1.32	-1.82	0.06
13	Chandauli	0.00	-10.42	-0.13	-6.68	0.03
14	Ayodhya	0.00	-0.25	-4.09	-0.76	0.03
15	Gorakhpur	0.00	-2.00	-0.53	-3.67	-0.87
16	Deoria	0.00	-6.41	0.66	-2.35	-0.25
17	Shrawasti	0.02	-6.62	-7.25	-1.65	0.95
18	Balarampur	0.00	-9.27	4.63	-1.51	0.80
19	Siddhartha Nagar	0.01	-7.85	-2.09	-0.72	1.46
20	Sant Kabir Nagar	0.01	-7.15	2.33	-1.50	0.59
21	Maharajganj	0.01	-11.92	0.16	-6.25	-1.10
22	Kushinagar	0.00	-1.10	3.33	-1.91	-0.13
23	Mau	0.00	-5.75	1.88	1.01	1.31
24	Sonbhadra	0.00	8.96	-0.73	2.29	0.73
25	Santravidas Nagar	0.00	3.88	2.85	0.06	1.33
26	Ambedkar Nagar	0.00	-1.00	-0.15	-0.90	0.02
27	Barabanki	0.02	-0.03	-0.17	0.24	0.33

*****Bold value shows the magnitude of trend significantly increasing or decreasing

3.4 Change point analysis for Ground water quality parameters

Monthly, annual, and seasonal time scales—that is, winter, pre-monsoon, monsoon, and post-monsoon months—were used to calculate the change point analysis of the observed ground water quality. Pettitt's test was used to analyze observed ground water quality data from 27 districts of Uttar Pradesh in order to determine the likelihood of a change year. The mean of the

subseries before and after the change point year was also computed in order to evaluate the change in mean. Table 3 displays the change point years at a monthly timescale, together with the means of the series preceding and after the change point year.

pH, EC and TH parameters change point was located in years 2015, 2005 & 2003 and its pre and post mean value are 7.936, 817.524 & 275.106 and 8.153, 757.712 & 244.143 in Prayagraj district. TDS & Ca change point found out in same year 2012 with pre and post mean value are 689.506 & 22.380 and 763.411 & 37.833 respectively. Azamgarh district show the change point of pH, TH and Ca in years 2004, 2017 & 2014 with pre and post mean value are 7.97, 212.52 & 19.68 and 8.02, 2741.29 & 37.73 respectively. Year 2011 change point of EC & TDS located with pre and post mean value are 700.86 & 725.85 respectively in Azamgarh district.

In Ambedkar Nagar district pH, EC, TH & Ca change point was detected in year 2007 and its pre and post mean value are 8.05, 697.02, 285.86 & 41.28 and 7.89, 649.86, 246.93 & 38.94 respectively. TDS change point found out in year 2004 with pre and post mean value is 695.75 and 684.61. In Bahraich district pH and TDS parameters change point was found out in years 2017 & 2008, its pre and post mean value are 7.90 & 650.80 and 7.72 & 745.30. In year 2011 change point was detected of EC, TH and Ca with pre and post mean value has 563.17, 215.67 & 26.09 and 668.16, 254.28 & 55.42 respectively. In Ayodhya station, EC, TDS, Total hardness and Calcium was changed in 2007 and before and after changes its mean are 605.98, 820.88, 276.91 and 37.52 respectively, and 570.64, 738.23, 239.06 and 35.52 respectively. Year 2017 pH was changed and its pre and post mean value are 7.92 and 8.05 respectively. At Station Ghazipur EC and Calcium was changed in 2012 with pre mean and post mean value is 642.61, 27.27 and 833.28, 38.66 respectively. Further PH and total hardness was changed in year 2017 its pre and post mean value are 7.92, 217.68 and 8.25, 327.50. TDS was changed in 2004 its pre and post mean value743.95 and 733.73. At district Gonda, total hardness and Calcium was changed in 2012 its pre and post mean value are 238.82, 31.88 and 245.51, 54.71. At Gorakhpur station, all parameter was changed in 2009 except PH with pre and post mean value are 794.30, 780.17, 324.21 and 72.21 and 678.55, 768.72, 260.59 and 51.39 respectively. And PH was changed in 2008 with pre and post mean value7.95 and 7.92 respectively. In station Jaunpur, the changed point year was found, 2013, 2009, 2011, 2017 and 2000 respectively with its pre and post mean value are 7.95,888.33, 753.41,282.63, 29.82 and 8.37, 733.35,770.53,146.63,20.19 respectively. In station Kushinagar all parameter was changed in 2009 except PH its pre and post mean value are 683.50, 707.69, 296.35, 55.18 and 652.79, 766.82, 258.67, 48.43. Station Maharajganj all parameter was changed in 2008 except 2008 TDS and its pre and post mean value 7.94, 752.15, 312.11, 73.01 and 8.01, 568.16, 225.11, 50.05 respectively. Its value was change in 2013 with its pre and post means 737.90 and 764.46 respectively.

Table 3: Change point data of ground water quality parameters

Prayagraj					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2015	2005	2012	2003	2012
mean_pre	7.936	817.524	689.506	275.106	22.380
mean_post	8.153	757.712	763.411	244.143	37.833
Azamgarh					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2004	2011	2011	2017	2014
mean_pre	7.97	700.86	725.85	212.52	19.68
mean_post	8.02	622.49	767.50	274.29	37.73
Ambedkar Nagar					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2007	2007	2004	2007	2007
mean_pre	8.05	697.02	695.75	285.86	41.28
mean_post	7.89	649.86	684.61	246.93	38.94
Bahraich					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2011	2008	2011	2011
mean_pre	7.90	563.17	650.80	215.67	26.09
mean_post	7.72	668.16	745.30	254.28	55.42
Ballia					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2007	2011	2001	2012
mean_pre	7.99	792.72	690.78	254.34	20.95
mean_post	8.31	695.43	724.89	228.93	38.86
Balarampur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2000	2017	2010	2017	2012
mean_pre	8.08	762.33	683.47	272.02	31.58
mean_post	7.89	486.40	760.30	184.00	47.36
Barabanki					
	pH	**EC (µS/cm at 25°C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2012	2005	2017	2007	2015
mean_pre	7.67	612.61	773.43	247.93	36.10
mean_post	7.86	603.80	695.47	246.76	42.68
Basti					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2010	2009	2017	2009	2012
mean_pre	7.88	808.57	722.49	316.52	38.07
mean_post	7.98	594.60	524.76	231.73	49.95

Chandauli					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2004	2014	2004	2017	2004
mean_pre	7.95	784.38	762.01	252.44	34.96
mean_post	7.89	640.84	773.96	168.31	33.24
Deoria					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2008	2008	2017	2008	2008
mean_pre	7.99	726.68	722.24	275.27	64.81
mean_post	8.03	602.33	738.27	230.65	52.48
Ayodhya					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2011	2007	2007	2007	2007
mean_pre	7.92	605.98	820.88	276.91	37.52
mean_post	8.05	570.64	738.23	239.06	35.52
Ghazipur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2012	2004	2017	2012
mean_pre	7.92	642.61	743.95	217.68	27.27
mean_post	8.25	833.28	733.73	327.50	38.66
Gonda					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2010	2017	2015	2012	2012
mean_pre	7.85	668.30	770.70	238.82	31.88
mean_post	7.97	496.80	726.14	245.51	54.71
Gorakhpur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2008	2009	2009	2009	2009
mean_pre	7.95	794.30	780.17	324.21	72.21
mean_post	7.92	678.55	768.72	260.59	51.39
Jaunpur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2013	2009	2011	2017	2000
mean_pre	7.95	888.33	753.41	282.88	29.82
mean_post	8.37	733.35	770.53	146.63	20.19
Kushinagar					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2008	2009	2009	2009	2009
mean_pre	7.96	683.50	707.69	296.35	55.18
mean_post	8.00	652.79	766.82	258.67	48.43
Maharajganj					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2008	2008	2013	2008	2008
mean_pre	7.94	752.15	737.90	312.11	73.01
mean_post	8.01	568.16	764.46	225.11	50.05
Mau					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2004	2006	2013	2009	2008
mean_pre	8.02	793.59	640.65	221.25	7.70
mean_post	8.06	728.71	666.91	236.01	23.10
Mirzapur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2015	2015	2009	2014	2010
mean_pre	7.87	749.39	743.39	218.71	10.73
mean_post	8.13	598.18	761.99	171.33	29.10
Pratapgarh					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2011	2008	2011	2014	2010
mean_pre	7.95	1032.74	790.21	288.26	18.19
mean_post	8.13	831.05	757.00	235.90	29.09
Sant Kabir Nagar					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2008	2012	2017	2013
mean_pre	7.91	682.36	774.53	233.80	38.56
mean_post	8.15	603.44	812.04	162.33	43.55
Santravidas Nagar					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2010	2009	2010	2000	2010
mean_pre	7.84	769.94	634.58	283.33	11.58
mean_post	8.01	876.47	683.91	241.74	31.02
Shrawasti					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**

CP_year	2017	2017	2017	2017	2011
mean_pre	7.92	598.56	797.67	229.47	33.37
mean_post	**8.17**	360.00	672.09	180.00	49.65
Sidharthnagar					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2010	2009	2010	2012
mean_pre	7.86	787.11	771.98	265.32	31.15
mean_post	8.30	653.26	739.38	240.01	51.04
Sonbhadra					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2017	2017	2011	2011	2009
mean_pre	7.99	607.19	708.29	203.53	44.70
mean_post	7.82	818.62	686.58	233.57	51.57
Sultanpur					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2007	2008	2017	2007	2007
mean_pre	8.06	766.63	714.02	286.10	42.54
mean_post	7.98	710.23	782.43	252.25	33.92
Varanasi					
	pH	**EC (µS/cm at 25 °C)**	**TDS (mg/l)**	**Total Hardness (mg/l)**	**Calcium (mg/l)**
CP_year	2015	2004	2009	2004	2000
mean_pre	7.85	665.96	762.06	245.39	34.67
mean_post	8.20	537.76	757.04	193.13	20.57

In Ballia district change point of pH, EC, TDS, TH and Ca parameters located in years 2017, 2007, 2011, 2001 and 2012, its pre and post mean value are 7.99, 792.72, 690.78, 254.34 & 20.95 and 8.31, 695.43, 724.89, 228.93 & 38.94 respectively. In Balarampur district show the change point of pH, TDS and Ca in year 2000, 2010 and 2012 with pre and post mean value are 8.08, 683.47 & 31.85 and 7.89, 760.30 & 47.36 respectively. EC and TH change point found out in year 2017 with pre and post mean value are 762.33 & 272.02 and 486.40 & 184.00. Year 2017 found the change point year for pH and TH in Sant Kabir nagar where its pre mean are 7.91, 233.80 and post mean 8.15, 162.33 respectively. Similar change point year for EC, TDS and Ca were found in 2008, 2012 and 2017 correspondingly and pre mean are 682.36, 774.53 and 38.56 while post mean are 603.44, 812.04 and 43.55 respectively.

At Shrawasti, Sidharth Nagar and Sonbhadra show the 2017 change point year for pH, pre means for these districts are 7.92, 7.86 and 7.99 while post mean are 8.17, 8.30 and 7.82 respectively. Similarly, 2017 found the change point year for EC, TDS and TH in Shrawasti district pre and post mean were identified 598.56, 797.67, 229.47 and 360.00, 672.09, 180.00 respectively. In Sonbhadra change point year same for TDS and TH was 2011, pre and post mean were 708.29, 203.53 and 686.58, 233.57 respectively.

At Santravidas Nagar year 2010 found the change point year for pH, TDS and Ca and 2009,2000 found the change point year for EC and TH. Pre and post mean for pH, TDS and Ca are 7.84, 634.58, 11.58 and 8.01, 683.91, 31.02 respectively. Pre and post mean for EC and TH are 769.94, 283.33 and 876.47, 241.74 respectively.

Year 2007 found the change point year of pH, TH and Ca in Sultanpur, its pre and post mean are 8.06, 286.10, 42.54 and 7.98, 252.25, 33.92 respectively. At Varanasi district change pint found in years 2015 for pH, 2004 for EC, 2009 for TDS, 2004 for TH and 2000 for Ca where its pre and post mean were found 7.85, 665.96,762.06, 245.39, 34.67 and 8.20, 537.76, 757.04,193.13, 20.57 respectively. Remains all districts found out the change point of pH, EC, TDS, TH and Ca in year from 2000 to 2018 with pre and post mean values, that shown in table 3.

The finding Singh and Hussian (2016) [18] is identified with significant increasing trend of EC and TDS but in this study found out the trend of EC is significant decreasing in seven districts such as: Basti, Gonda, Jaunpur, Chandauli, Shrawasti, Balrampur and Siddhartha nagar. Collect the pH result is significant increasing trend in Jaunpur, Ghazipur, Shrawasti and Siddhartha nagar further these districts show the amount of pH is high. The acceptable pH range varies from 6.5 to 8.5 in all districts. Water is not fit for human consumption if its pH is lower than 6.5 or higher than 8.5. The pH values that were collected for this study are ideal for human consumption.

4. Conclusion

The study is conduct to evaluate the ground water quality of 27 districts of Uttar Pradesh. The result is that the pH, EC, TDS, TH and Ca parameters are within pollution limits at almost selected area of study. However, the pH, EC, TDS, TH and Ca value are exceeded ranges 0.77015 to 4.1983, -3.4986 to 2.9388, -3.7784 to 3.2886, -3.0088 to 3.2886 and -1.6463 to 3.8484. Trend analysis of the ground water quality parameters can be useful in selecting which ones to test frequently in order to periodically evaluate the condition of the ground water quality. This will enable regulatory bodies to more easily implement control measures and provide alerts when the quality of ground water starts to deteriorate.

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