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Analysis of Groundwater Quality in Dhaka Division

by

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بِسْمِ اللَّهِ الرَّحْمَٰنِ الرَّحِيمِ

In the name of Allah, The Most Gracious and The Most Merciful

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An undergraduate thesis submitted to the Department of Civil & Environmental Engineering of Islamic University of Technology in partial fulfillment of the requirements for the degree of Bachelor of Science in Civil and Environmental Engineering

Department of Civil and Environmental Engineering (CEE)

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Approval

This is to certify that the work presented in this thesis was carried out by Md Atif Arham and Md. Jahim Uddin Shorif entitled as "**Analysis of Groundwater Quality in Dhaka Division**" under the direct supervision of Dr. Md. Rezaul Karim, Professor, Department of Civil and Environmental Engineering, Islamic University of Technology - IUT. The work has been approved, in partial fulfillment of the requirements for the Bachelor of Science degree in Civil Engineering.

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Declaration

We hereby declare that the undergraduate research work reported in this thesis has been performed by Md Atif Arham and Md. Jahim Uddin Shorif under the supervision of Professor Dr. Md. Rezaul Karim and this work has not been submitted elsewhere for any purpose (except for publication).

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ABSTRACT

The primary reason that may be identified for significant deterioration in groundwater quality parameters is the rapid change in climate and temporal variability of water supply system. The main objective of this study is to identify the trend change according to time and the co relation between the parameters in 18 different locations of Dhaka division for 40 years' time cycle. To characterize the water quality of the sites, Man Kendal test ,Modified Man Kendal, Sens Slope are used for trend analysis. Besides, spatio temporal variation of 15 groundwater quality (Ca,Mg,Na,pH,CO_2,TDS,K,Cl,CO_3,SO_4,NO_2,Fe,Si,F,HCO_3)are determined by mapping in GIS. For establishing correlation between parameters Pearsons Correlation matrix has conducted. The individual hydro chemical characteristics of every stations is demonstrated by Piper Diagram. The results indicated the consequential increasing trend at almost 30% of the sites in all the parameters. Besides, the correlation matrix also provides a strong correlation between the Na & Cl , Mg & SO_4 that causes salinity and total hardness. The hardness also identified from piper diagram as well. TDS (Total Dissolved Solid) and the increasing of HCO_3 is also a great concern for the study areas. Finally, the groundwater quality in Dhaka division is investigated by whiskers plot,which showed that the groundwater quality of 43% stations are beyond the standard limit.

1 INTRODUCTION

1.1 Background

Dhaka Division covers an area of 31026.51 square kilometers and is located between 22°51' and 25°25' north latitudes and 89°19' and 91°15' east longitudes. It is bounded on the north by kurigram district and the Indian state of Meghalaya, on the south by bagerhat, pirojpur, barisal, and chandpur districts, on the east by sunamganj, habiganj, brahmanbaria, comilla, and Chandpur districts, and on the west by narail, magura, jhenaidah, kushtia, pabna, Siraj. Dhaka is surrounded by a flat plain bordered by the Meghna, Padma (Ganges [Ganga], and Jamuna (Brahmaputra) rivers. The plain is traversed by a network of streams and rivers, the most important of which are the Dhaleswari, Buriganga, and Sitalakhya. Rice, jute, sugarcane, and oilseeds are important crops, and there is considerable cattle rearing. Dhaka division maximum elevation is 359 m and the Average elevation is 14 m. [https://en-gb.topographic-map.com/maps/ro4w/Dhaka-Division/] .This study have covered 18 different locations of Dhaka Division which are Faridpur Sadar, Gazipur (Sreepur), Gopalganj Kashiani, Gopalganj Sadar, Kishoregonj Sadar, Kishoreganj Bhairab, Madaripur Sadar, Mohammadpur, Motijheel, Munshiganj Sreenagar, Narsingdi Sadar, Rajbari (Pangsha), Rajbari Sadar, Sherpur Sadar, Tangail(Madhupur), Tangail Sadar, Tangail (Mirzapur), Textile Mill Tangail. The annual average temperature showed increasing trend over the period of study for Dhaka, Mymensingh and Faridpur by 0.02 0C, 0.003 0C and 0.010 0C per year, respectively (Nakibul et al., 2013). Annual total rainfall in Dhaka and Mymensingh increased by 2.330 mm and 2.171 mm each year, respectively (Fig. 4). Annual total rainfall decreased by 5.996 mm, 4.179 mm, and 15.10 mm per year in Tangail, Faridpur, and Madaripur, respectively (Fig. 4). Rainfall in Madaripur has decreased drastically, and the coefficient of determination was 0.158. (Choudhury (2004) observed that the yearly average rainfall in Dhaka was increasing by 2.2 mm per year (Nakibul et al., 2013).

Dhaka division is consist of Madhupur clay and red soil. The Madhupur Clay underpins the Madhupur and Barind tracts, which account for around 8% of the country. The similar structure may be seen on the Akhaura Terrace and the peak of the Lalmai hills. Unweathered Madhupur Clay is astonishingly uniform in appearance over its whole length, both vertically and laterally. It consists of an unconsolidated clay layer around 10m thick in Dhaka, although it appears to thin down towards the east and grow considerably thicker towards the west of the Barind tract. Red soils are tropically weathered soils with a high content of iron and/or alumina sesquixides.

They contain a low concentration of alkalis and alkaline earths. They come in a variety of chemical compositions. Silica concentration ranges from low to considerable and is typically found as kaolinite when significant levels are present. Siyanbola Samuel Malomo, (1977) soils are prevalent in areas with limited rainfall and are incapable of holding moisture. Because of its porous and friable nature, red soil has lesser strength than other soils. Red soils cover around 8% of the nation in Bangladesh. Weathering of igneous rocks with a high iron content produces red soil.

Every day, around 2.3 Mm^3 of water is necessary to meet Dhaka's demand. To supply this demand of more over 14 million people, approximately 2.0 Mm^3 of groundwater is extracted from the upper Plio-Pleistocene Dupi Tila aquifer. Dhaka Water Supply and Sewerage Authority (DWASA) tubewells and over 2000 private tubewells of varied depths have been extracting groundwater from this aquifer. The unrestricted abstraction of groundwater has caused issues with the city's water resource management. Because of uncontrolled development, recharging areas are gradually shrinking. As a result, the process of natural water recharge to the aquifer has not kept pace with the rate of water removal from it during the previous three decades.Pleistocene alluvium fills the city's dissected uplands, while alluvium of recent river-borne deposits covers the city's low lying flood plains. The Pleistocene Madhupur Clay, characterized by reddish plastic clay with silt and extremely fine sand, overlies the Pliocene Dupi Tila Formation, which forms the primary aquifer. The Dupi Tila Formation is made up of medium to coarse yellowish brown sand with some gravel. Recent Holocene? alluvial floodplain deposits cover the incised channels and depressions. The upper aquifer system (first aquifer) is defined as: (1) an upper formation composed of very fine to fine sand, in places associated with traces of silt, that extends down to a depth of 30 to 90 m, (2) a middle part composed of fine to medium sand, in places associated with coarse sand at depth, that extends down to a drilling depth of 100 to 240 m with thicknesses ranging from 50 to more than 200 m.

The first aquifer is recharged primarily by horizontal flow from adjacent regions, with a part from vertical percolation of rain and floodwater. The Dupi Tila Aquifer is recharged by topographically induced vertical leaking through the Madhupur Clay (Ahmed 1994; Hassan et al. 1998a). The city's rechargeable surface area is shrinking because to increased urbanization. The rechargeable surface area is shrinking day by day as a result of the unplanned urbanization of buildings, roads, and concrete pavements. Furthermore, the compact top clay layer in the subsurface prevents vertical recharging, despite the fact that the average annual rainfall in the metropolitan region is around 1800 mm. Lowering the water table lengthens flow routes, which increases the time necessary for recharging and diminishes vertical hydraulic conductivity owing to pore drying (Morris et al. 2003).The contribution of rivers to the aquifer system appears to be restricted, as evidenced by the discrepancies in river stages and groundwater levels.

1.2 Objective of the Study

- Analyze the trend of groundwater quality parameters.
- Correlation between the parameters of the individual stations.
- Help in understanding the sources of the dissolved constituent salts in water.

2 LITERATURE REVIEW

2.1 Current groundwater supply conditions in Dhaka division

Groundwater quality is critical for drinking, irrigation, and residential use. In Bangladesh, groundwater quality has become a serious problem. (Shahidullah et al., 2000; Raihan and Alam, 2008; Bahar and Reza, 2010; Rahman et al., 2012a,b; Biswas et al., 2014). The central section of Bangladesh is experiencing diminishing groundwater quality owing to a variety of factors such as river natural direction shifts, inefficient water body management, climate variability, and human activities. Water quality in central Bangladesh is also impacted by arsenic pollution and mobilization into groundwater. BGS, DPHE, 2001..Heavy metal pollution, on the other hand, is a major health risk in central Bangladesh due to its toxicity, persistence, and bioaccumulation. Continuous monitoring and evaluation of groundwater quality therefore aids in the preservation of people and the environment (McCutcheon et al., 1993; Meharg and Rahman, 2003; Islam et al., 2015). Islam et al. (2015) discovered that Fe and Mn concentrations in groundwater in Bangladesh were greater than other heavy metals. Previous research has found significant salt levels in surface water along the shoreline (Shammi et al. 2017), as well as coastal regions such as Khulna (Shammi et al. 2016a), and Gopalganj (Shammi et al. 2012, 2016b). Studies showed that about 90% drinking water (Mridha et al. 1996) and 75% irrigation water are (Shahid et al. 2006) directly drawn from groundwater resources in Bangladesh.

Groundwater, mostly extracted from the Dupi Tila aquifer, was the source of communal water supply in Dhaka and other regional cities in Bangladesh. Surface water (mostly from ponds, colloquially known as pukur) and water from tubewells and (or) dugwells (shallow wells) were utilized for drinking and other domestic uses in other suburban areas and most rural Bangladesh. Because of inadequate infrastructure at the time, sufficient groundwater was not extracted for drinking or irrigation. Despite the fact that Bangladesh is recognized for its rivers, marshes, and ponds, there has always been a lack of dependable fresh surface water that is free of bacteriogenic contamination.. In Sunamganj, the major ions present in groundwater were calcium, magnesium, sodium, bicarbonate, sulphate and chloride. Other ions that may be found in low concentrations were potassium, carbonate, nitrate, iron, boron, and silica.

2.2 Previous works on groundwater quality

There is no historical record of groundwater quality, therefore it is impossible to determine what changes have occurred in the quality of Dhaka city groundwater over time.

Data on groundwater quality are available beginning in 1970. BWDB monitoring data suggest that the content of Chloride and Nitrate has grown over time (Ahmed et al, 1998). Several surveys revealed an increase in the electrical conductivity (EC) of groundwater in the upper Dupi Tila aquifer. Water quality is relatively bad in regions such as Hazaribag when compared to other areas (Zahid et al, 2006). Groundwater near the Buriganga is impacted by polluted surface water leaks (Darling et al., 2000). However, the quality of Dhaka groundwater is generally adequate for all metrics.Previously, the groundwater quality works only covered in central part of Bangladesh like Dhaka City,Gopalganj,Gazipur area and analyze the data of Fe, As, Na, Cl . Dhaka's water supply system is primarily reliant on subsurface water sources. Because the pace of groundwater recharge is slower than the rate of extraction, the GWL has been falling. Groundwater levels were dropping at an alarming rate around the city, with no meaningful rebound even during the rainy season. The regional variance in groundwater level depletion trends revealed that the south-central metropolitan regions saw the greatest and fastest groundwater depletion, making them more vulnerable to aquifer drying out. The current study attempted to investigate groundwater quality in the Dhaka region and to discover correlations between several quality indices. Zahid and Bodruddoha (2018) discussed the current state of groundwater quality in Dhaka's Hazaribag tannery area and discovered trace elements in groundwater.

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3 METHODOLOGY

3.1 Data Collection

Groundwater samples in the research region are typically taken during the pre-monsoon season (March to May) at 18 randomly selected sites; the locations of the sites are indicated in Fig1. The pre-monsoon season groundwater quality values for an 43-year period (1975–2018) were gathered from the BWDB. The samples were chemically examined by the department to ascertain the following water quality parameters calcium (Ca), magnesium (Mg), sodium (Na), potassium (K), iron (Fe), sulphate (SO_4), chloride (Cl), carbonate (CO_3), bicarbonate (HCO_3), nitrate (NO_3), silica (SiO_2), pH, EC, total dissolved solids (TDS), and hardness. On the GIS platform, these data were utilized for univariate and multivariate statistical analysis to determine the trend change according to time cycle period. Those characteristics are determined for understanding the sources of dissolved constituent salts in water. A key problem of this work was the irregular nature of water quality observations throughout space and time within a district, which results in either a lack of acceptable continuous temporal data or an inadequate geographical representation of the study region. For those missing data, mice analysis is used for missing data imputation and minimize the possible errors that could occur due to lack of data availability. To accommodate for changing sample sizes, percentages of observations exceeding environmental criteria were determined, together with descriptive statistics, to support conclusions regarding trending changes in water quality. Groundwater physicochemical data were examined for water type using Grapher (Golden software, Golden, CO, USA) and correlation of water quality parameters using Pearson correlation using R studio.

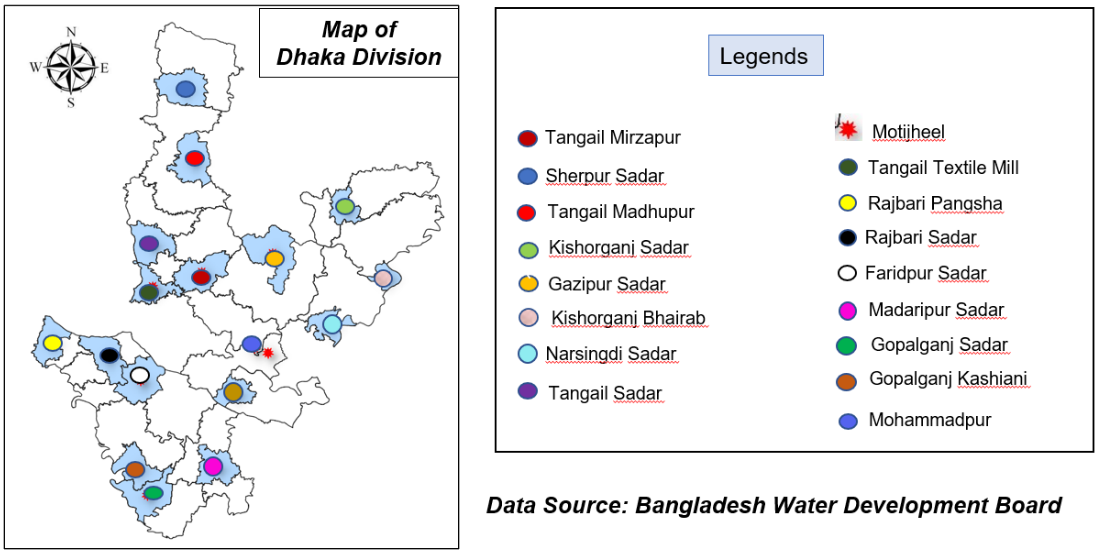


Fig. 1 Location of the Study Area

3.2 Methods

3.2.1 Mann-kendall test

Mann first proposed the Mann-Kendall (MK) test in 1945, and Kendall expanded on it in 1975. This non-parametric test is commonly used to determine linear and non-linear time series patterns in hydrological and meteorological data sets. The trend was identified using data from 18 different observation stations. It is a simple method that can handle the highest values, missing values, and values below a certain limit. The test is applicable for non-normal distributions. The MK test value for the data S statistics is calculated as follows:

$$S = \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} sgn\ (x_j - x_i)$$

Where, x_j and x_i address respectively data in the j and i years, individually, and n addresses the time length of the statistical period. In the next equation, a pair of estimation values were correlated thought subtractions with growing values = +1, declining values = 1, no change = 0, and are written as:

$$sgn(x_j - x_i) = \begin{cases} +1, if\ (x_j - x_i) > 0 \\ 0,\ if\ (x_j - x_i) = 0 \\ -1,\ if\ (x_j - x_i) < 0 \end{cases}$$

Variance denotes the variance of S with a zero mean for $n \geq 8$. The statistic S may be stated using the mean (E) and the variance (V), as follows:

$$V(S) = \frac{n(n-1)(2n+5) - \sum_{i=1}^{m} t_i(t_i-1)(2t_i+5)}{18}$$

In this equation, the quantity of data is n, the number of ties is m, and the number of ties for the ith value is t_i. In cases when n > 10, the standard normal test statistic Z for the normal distribution at the 95 percent and 99 percent confidence interval levels is calculated for the data point as follows:

$$Z = \begin{cases} \frac{S-1}{\sqrt{Var(s)}} & S > 0 \\ 0 & S = 0 \\ \frac{S+1}{\sqrt{Var(s)}} & S < 0 \end{cases}$$

Positive Z values suggest that trends are increasing, whereas negative Z values indicate that trends are diminishing. The α significance level is used to test trends. When $|Z| > Z_{1-\alpha/2}$, the null hypothesis H_0 of no trend is rejected, and the alternative hypothesis H_1 of a substantial trend is accepted. The usual normal distribution in the table provides $Z_{1-\alpha/2}$. If the estimated Z-statistics value is less than or greater than the crucial Z-statistics value obtained from the normal distribution of the table, the null or alternative hypothesis is accepted or rejected. We used the MK test to see if a trend in groundwater quality parameters was statistically significant, with significance thresholds of = 0.05 (or 95% confidence intervals) and = 0.01 (or 99% confidence intervals) in this trend study.

3.2.2 Modified Mann–Kendall

The modified VAR(S) statistic may be calculated as follows: (Hamed and Rao 1998)

$$VAR(S) = \left(\frac{n(n-1)(2n+5)}{18}\right) . \left(\frac{n}{n_e^*}\right)$$

The correction factor (n/n^*_e) is now adjusted to the autocorrelated data as

$$\left(\frac{n}{n_e^*}\right) = 1 + \left(\frac{2}{n^2 - 3n^2 + 2n}\right) \sum_{f=1}^{n-1} (n-f)(n-f-1)(n-f-2)\rho_e(f)$$

$\rho(f)$ represents the autocorrelation function between ranks of observations and can be estimated as:

$$\rho(f) = 2\sin\left(\frac{\pi}{6}\,\rho_e(f)\right)$$

3.2.3 Sen's Slope

The slope (trend) of n data pairs was estimated using Theil–Sen (TS) test. n this study, the TS was used to determine the size (%) of the trend. For this test, the spacing between time series data points is evenly spaced and sorted by ascending order by time.

The slope of Sen may be determined as follows:

$$Q = \frac{x_j - x_i}{j - i}$$

Where, x_j and x_i are values at periods j and i respectively, in. The median of Sen's slope is calculated by sorting the total N values of Q from least to largest:

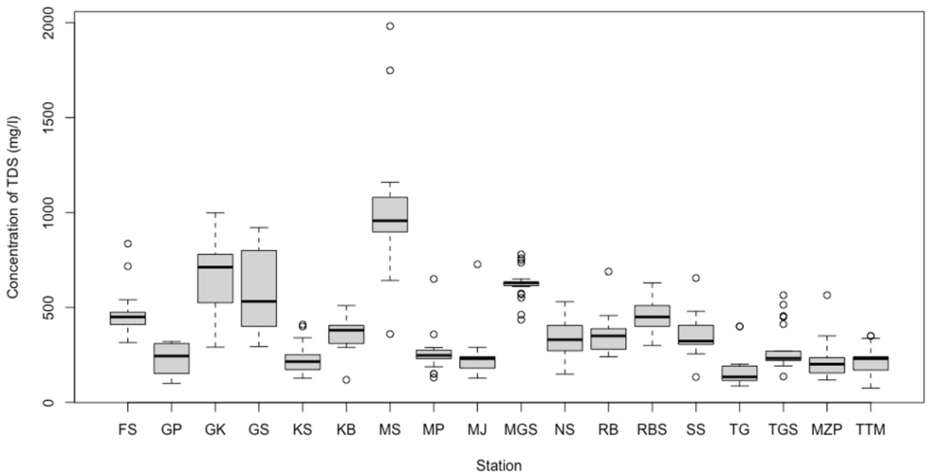
$$Q_{med} = \{Q_{(N+1)/2}, If\ N\ is\ odd$$

$$Q_{med} = \{\frac{Q_{\left(\frac{N}{2}\right)} + Q_{\left(N+\frac{2}{2}\right)}}{2}, If\ N\ is\ even$$

In those Equations, Q_{med} represents the direction of the data trend, and its value represents the size of the trend. Sen's slope is a robust assessment of trend magnitude that has been widely utilized in finding trend slope in hydrological time series.

3.2.4 Box and Whisker plot

A variability study of groundwater quality parameters is critical for researchers in making decisions. The compact structure of box and whisker plots (Tukey, 1977) facilitates side-by-side comparisons of numerous datasets, which can be difficult to grasp using more comprehensive representations, such as the histogram (Banacos, 2011). These plots graphically illustrate the statistical distribution in a way that a wide variety of people can comprehend. The box and whisker plot takes the following form: a centre horizontal line indicating the median, and top and bottom horizontal lines representing the interquartile range (shown by the box). The bottom and top horizontal lines in the boxes represent the 25th and 75th percentiles, respectively. Vertical lines are used to represent the outside ranges (as shown by the whiskers). If the median line is considerably pushed away from the centre, this may indicate skewness in the distribution. The length of the interquartile range (IQR), as illustrated by the box, is a measure of the relative dispersion of the centre 50% of a dataset, just as the length of each whisker is a measure of the relative dispersion of the dataset's outer range.



Whisker plots of 15 groundwater quality parameters for 18 stations (FS - Faridpur Sadar, GP - Gazipur Sreepur, GK - Gopalganj Kashiani, GS - Gopalganj Sadar, KS - Kishoreganj Sadar, KB - Kishoreganj Bharab, MS - Madaripur Sadar, MP - Mohammadpur, MJ - Motijheel, MGS - Munshiganj Sreenagar, NS - Narsingdi Sadar, RB - Rajbari, RBS - Rajbari Sadar, SS - Sherpur Sadar, TG - Tangail, TGS - Tangail, MZP - Mirzapur, TTM - Textile Mill Tangail

Fig. 2 Box Whiskers Plot

3.2.5 Piper Diagram

A Piper diagram is a pictorial approach developed by Arthur M. Piper in 1944 to aid in understanding the origins of dissolved component salts in water. This approach is predicated on the assumption that cations and anions in water are present in sufficient quantities to ensure the electroneutrality of the dissolved salts, i.e. the algebraic sum of the electric charges of cations and anions is zero. A Piper diagram depicts the chemistry of a water sample or samples graphically. Separate ternary plots depict the cations and anions. The cation plot's apexes are calcium, magnesium, and sodium cations, as well as potassium cations.

To calculate piper diagram initially the concentration value of every cation and anion have to convert into relative concentration and then plot it into the ternary diagram by the help of Grapher software.

Concentration (Mili equivalent/liter): $\frac{Concentration\left(\frac{mg}{L}\right)*Valance}{Atomic\ weight}$

Relative Humidity (%): $\frac{Cation\ concentration\ (meq)*100\%}{Sum\ of\ all\ cation\ concentration\ (meq)}$

3.2.6 Pearson's Correlation

Pearson's correlation coefficient is calculated by dividing the covariance of the two variables by the product of their standard deviations. The definition takes the form of a "product moment," which is the mean (the first moment around the origin) of the product of the mean-adjusted random variables; hence, the term includes the modifier product-moment.

The correlation factor is detonated by (r) and there is a range for this r value that can determine whether the relation between two continuous variables are strong or weak. If the value of r is between 0.5 to 0.7 then it is moderate, if the value higher than 0.7 then it is strong correlation. So, the values of r are "+ 1 or - 1," they are considered high correlation coefficient values, indicating full correlation, i.e., functional dependency, between two variables and the value nearer to the zero can be regarded as no co-relation between the parameters.

$$r = \frac{\sum(x_i - \bar{x})(y_i - \bar{y})}{\sqrt{\sum(x_i - \bar{x})^2 \sum(y_i - \bar{y})^2}}$$

r = correlation coefficient

$x_i \; = values\ of\ the\ x - variable$ in a sample

$\bar{x}$= mean of the values of the x-variables

y_i = $values\ of\ the\ y - variable$ in a sample

$\bar{y}$= mean of the values of the y-variables

4 RESULTS AND DISCUSSION

4.1 Trend Analysis

Table 4 and Figure 5 present a summary of the trend analysis for 18 stations. The Mann-Kendall test, Modified Mann-Kendall test and Sen's slope estimator were used to analyze 15 variables. Among these variables, with a Kendall test statistic (Z) value of zero means no change, greater than zero means positive and less than zero means negative change.

Table 1 Man Kendal Test

No	Station Name	TDS	CALCIUM	MAGNESIU	SODIUM	POTASSIUM	CHLORIDE	BICARBONA	SULPHATE	NITRATE	IRON	SILICA	FLUORIDE	CARBONDIC	PH	CARBONAT
1	Faridpur Sadar	-1.92	-0.89	-1.47	-0.72	-0.79	0.17	-0.30	-2.35	0.00	-0.55	2.73	1.02	1.52	-3.09	0.15
2	Gazipur (Sreepur)	1.87	0.40	0.65	-0.80	0.65	2.14	2.21	-1.50	0.70	1.17	3.04	1.76	1.25	-1.72	-0.33
3	Gopalganj Kashiani	-1.22	-2.91	-1.54	-0.34	-1.12	-2.14	-0.98	0.54	-0.56	-2.70	1.41	0.29	-0.82	-0.95	-0.1613,
4	Gopalganj Sadar	1.30	1.17	-0.24	-0.69	-3.26	0.07	1.70	0.13	1.07	-4.53	2.90	1.66	2.07	-1.86	-0.25
5	Kishoregonj Sadar	-1.33	1.90	0.16	-0.15	0.40	1.86	0.99	-0.26	0.55	-0.18	2.09	2.07	2.87	-2.65	-0.11
6	Kishoreganj Bhairab	-0.94	1.45	-2.41	-2.53	1.08	-1.36	0.91	-0.19	0.31	-1.95	0.21	0.75	3.62	-2.22	0.79
7	Madaripur Sadar	0.65	0.52	-3.27	-0.50	-1.31	1.14	0.05	-1.09	1.18	-1.09	0.23	0.80	3.45	-2.61	1.80
8	Mohammadpur	0.45	0.74	0.62	0.40	-2.03	1.59	1.65	0.51	-0.60	2.49	1.90	-0.40	2.01	-0.08	0.00
9	Motijheel	0.54	2.31	-1.39	-1.78	2.31	0.25	2.13	0.28	-0.20	2.25	-0.65	-1.11	2.89	-0.57	-0.80
10	Munshiganj Sreenagar	-0.27	-0.85	-0.05	0.24	-0.05	-0.61	-0.50	-0.11	1.17	-2.28	0.99	-1.51	0.56	-1.51	0.64
11	Narsingdi Sadar	-1.72	1.06	-1.75	-1.67	1.94	-2.22	1.27	0.00	1.71	-2.18	0.34	1.43	3.18	-1.30	0.16
12	Rajbari	0.84	1.78	-2.50	1.20	-0.29	0.44	1.75	-2.22	0.00	-1.15	2.11	1.02	3.15	-3.09	-0.14
13	Rajbari Sadar	2.39	-0.07	-2.39	-0.14	-1.24	3.14	-1.80	-0.05	0.52	-0.05	-0.45	0.83	3.67	-3.30	2.45
14	Sherpur Sadar	0.12	1.72	-0.37	-0.94	0.53	-2.58	1.67	0.08	0.55	-1.91	-0.55	-0.55	0.55	-0.68	1.45
15	Tangail	0.11	1.78	0.00	-0.66	1.89	2.26	2.54	-0.96	1.18	-0.24	2.07	1.92	3.04	-2.07	1.87
16	Tangail Sadar	1.28	1.17	-2.49	-2.17	3.09	-0.46	1.19	0.36	2.57	-1.15	3.07	0.25	2.54	-1.15	0.49
17	Mirzapur	-0.59	0.28	-0.89	-0.68	0.24	0.35	0.47	-1.64	-0.14	0.98	1.01	-0.07	-0.57	-0.14	0.76
18	Textile Mill Tangail	0.46	2.33	0.00	2.44	1.35	3.82	0.42	2.36	0.95	-1.19	1.66	1.37	-1.26	-2.19	0.64

From the table, we can see that for TDS most of the stations are in positive trends except Faridpur Sadar, Gopalganj(Kashiani), Munshiganj Sreenagar, Narsingdi Sadar and Mirzapur. A positive trend means over time TDS concentration will increase and a negative trend means decreasing.For TDS significant negative trend occur at faridpur Sadar station and positive trend at Gazipur(Sreepur). For Calcium significant negative trend occur at Gopalganj Kashiani station and positive trend at Textile Mill Tangail. For Magnesium, a significant negative trend occurs at Madaripur Sadarstation and a positive trend at Mohammadpur.

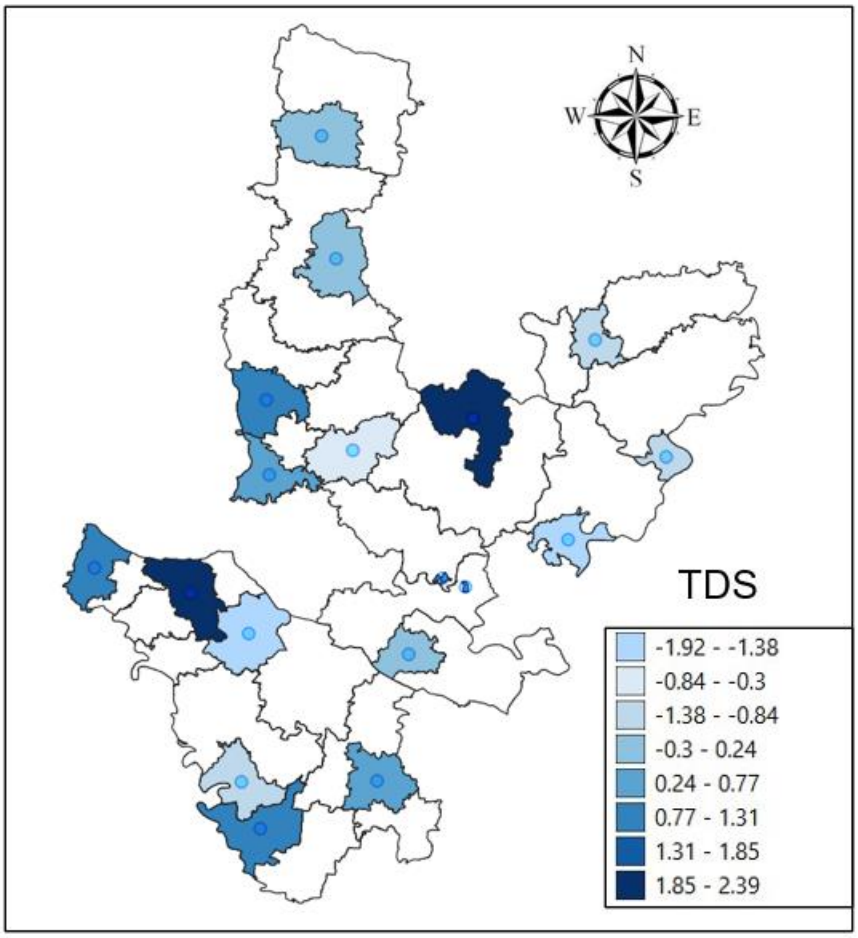


Fig. 3 Man Kendal Test GIS Mapping

Geology is important in the dynamics of groundwater levels in the research region. Furthermore, groundwater levels have a substantial impact on groundwater quality because groundwater quality indicators are diluted during the post-rainy season owing to recharge from rainfall. Sen's slope test was used in this work to determine the slope character (positive/negative) of trends. A positive slope indicates that over time concentration increase and a negative trend indicate over time concentration decrease. Slope zero means no change occurs over time.

Table 2 Sen's Slope

No	Station Name	TDS	CALCIUM	MAGNESIU	SODIUM	POTASSIUN	CHLORIDE	BICARBON/	SULPHATE	NITRATE	IRON	SILICA	FLUORIDE	CARBONDIOXIDE	PH	CARBONATE
1	Faridpur Sadar	-3.88	-0.88	-0.37	-0.11	0.00	0.00	-0.35	-0.50	0.00	-0.04	0.34	0.00	4.28	-0.07	0.00
2	Gazipur (Sreepur)	3.00	0.12	0.04	-0.02	0.00	0.26	2.62	-0.16	0.01	0.06	1.89	0.00	0.53	-0.03	0.00
3	Gopalganj Kashiani	-7.14	-4.18	-1.32	-0.09	-0.05	-0.73	-4.00	0.00	-0.02	-0.38	0.18	0.00	-2.14	-0.01	0.00
4	Gopalganj Sadar	6.00	1.25	0.00	-0.19	-0.36	0.00	5.00	-0.75	0.03	-0.36	0.46	0.00	2.21	-0.03	0.00
5	Kishoregonj Sadar	-2.24	0.68	0.00	0.00	0.00	0.20	1.83	0.00	0.01	-0.01	0.90	0.01	0.68	-0.05	0.00
6	Kishoreganj Bhairab	-2.47	0.52	-0.62	-0.77	0.01	-0.57	2.44	0.00	0.00	-0.09	0.07	0.00	4.48	-0.04	0.00
7	Madaripur Sadar	2.44	0.37	-1.38	-0.43	-0.05	4.35	0.00	-0.03	0.03	-0.02	0.00	0.00	4.52	-0.06	1.15
8	Mohammadpur	1.25	0.10	0.03	0.03	-0.12	0.28	2.01	0.07	-0.01	0.01	0.95	0.00	1.67	0.00	0.00
9	Motijheel	0.50	0.43	-0.13	-0.32	0.12	0.02	4.66	0.01	0.00	0.01	-0.15	-0.01	2.27	-0.01	0.00
10	Munshiganj Sreenagar	0.00	-0.64	0.00	0.00	0.00	-1.25	-1.21	0.00	0.04	-0.21	0.06	-0.01	0.33	-0.02	0.00
11	Narsingdi Sadar	-5.18	0.43	-0.68	-0.65	0.09	-1.04	2.33	0.00	0.06	-0.17	0.03	0.01	1.33	-0.03	0.00
12	Rajbari	1.67	4.45	-0.62	0.11	0.00	0.10	14.09	-0.16	0.00	-0.10	0.55	0.00	8.91	-0.06	0.00
13	Rajbari Sadar	6.56	0.00	-0.48	-0.01	0.00	0.57	-4.84	0.00	0.01	0.00	-0.05	0.00	33.98	-0.05	1.16
14	Sherpur Sadar	0.00	0.63	-0.02	-0.49	0.00	-1.77	8.17	0.00	0.01	-0.25	-0.13	0.00	0.07	0.00	0.12
15	Tangail	0.00	0.76	0.00	-0.01	0.02	0.62	3.33	0.00	0.03	-0.04	0.73	0.01	5.00	-0.03	0.08
16	Tangail Sadar	1.38	0.40	-0.37	-0.34	0.18	-0.12	2.20	0.00	0.08	-0.21	2.10	0.00	1.11	-0.02	0.00
17	Mirzapur	-1.36	0.09	-0.17	-0.04	0.00	0.05	0.55	-0.20	0.00	0.08	1.15	0.00	-0.05	0.00	0.00
18	Textile Mill Tangail	2.00	1.02	0.00	0.21	0.09	0.88	1.00	1.06	0.05	-0.22	0.89	0.01	-0.67	-0.04	0.00

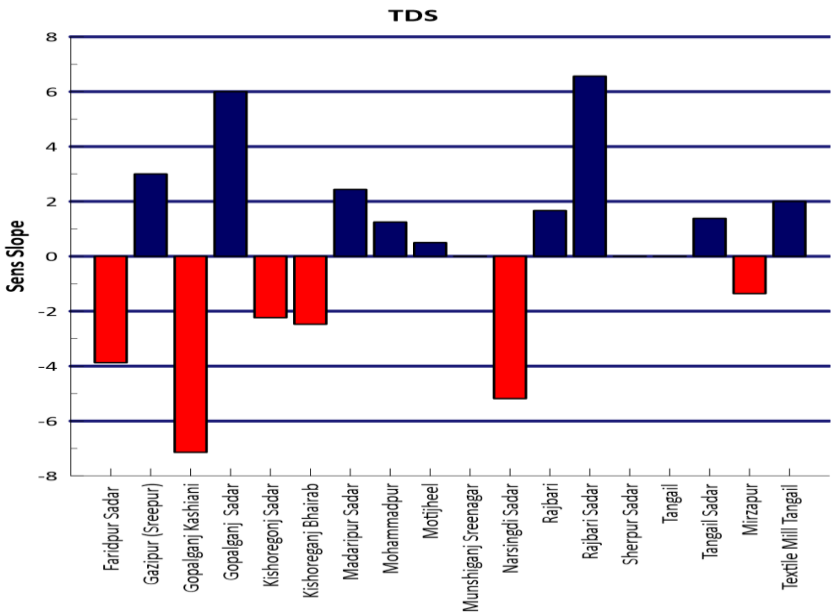


Fig. 4 Sen's Slope

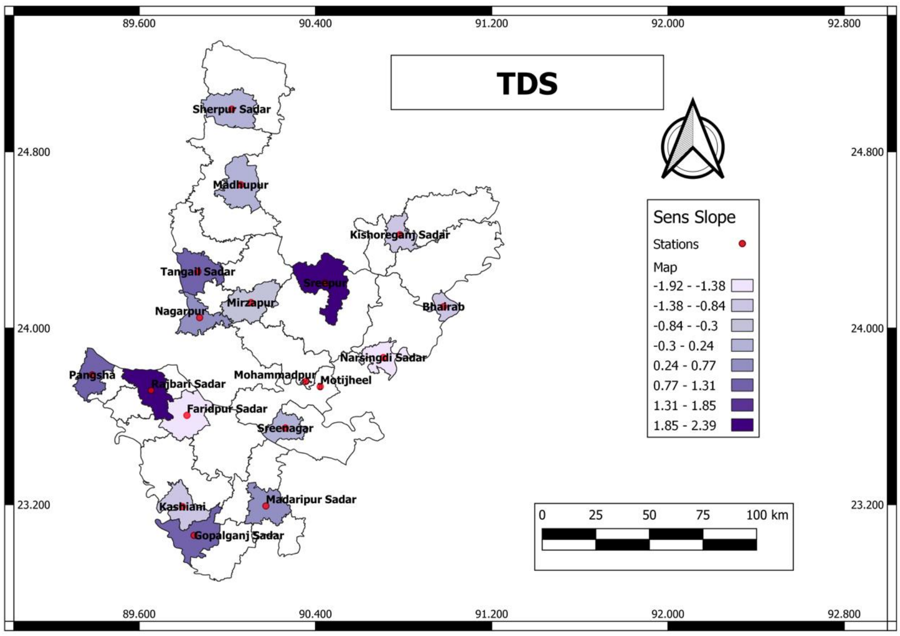


Fig. 5 Sen's Slope GIS Mapping

4.2 Major chemical composition of groundwater

Piper Diagram represents the classification of the water according to hydro chemical facies and different kinds of prominent ions .Piper (1944)The relative concentration of groundwater quality is plotted on the diagram and identify the primary characterization of water. The two lower triangles indicate the major cations and anions which were combinedly projected on the upper middle diamond.The diagram graphically explains the variations of cations and anions of different time series in every individual stations.

From the diagram, it is detected that the majority of the groundwater samples of every stations except Madaripur and Tangail Mirzapur were centered in the diamond's left corner, indicating that the groundwaters in the examined region were predominantly rich in Ca^{2+}, Mg^{2+}, and HCO_3.In Madaripur Sadar, Na+K & Cl have the most influence at the middle of the periodic timeline. It identify that the Madaripur Sadar have a slightly salt constituents in water composition but now it is in mix type condition. All other 17 stations have alkali type water which distinguish that the hardness is presence in the samples.

In this study, it is observed that the most dominant anion is HCO_3 which is predominantly high in every stations. The water contains HCO_3 equivalent fractions among total anions of up to 0.99 from lower value 0.80 on average for every individual stations. In Munshiganj and Madaripur Sadar the anion become change from HCO_3 to Cl and in case of Tangail Sadar the water quality become change to no dominance zone from high Alkali HCO_3. On the other hand Tangail (Mirzapur) contains totally opposite hydro chemical facies like it become HCO_3 from no dominance zone.From the result it is noticed that the Madaripur sadar has the highest domination of Cl anions which is almost 80% of total dissolved anions.

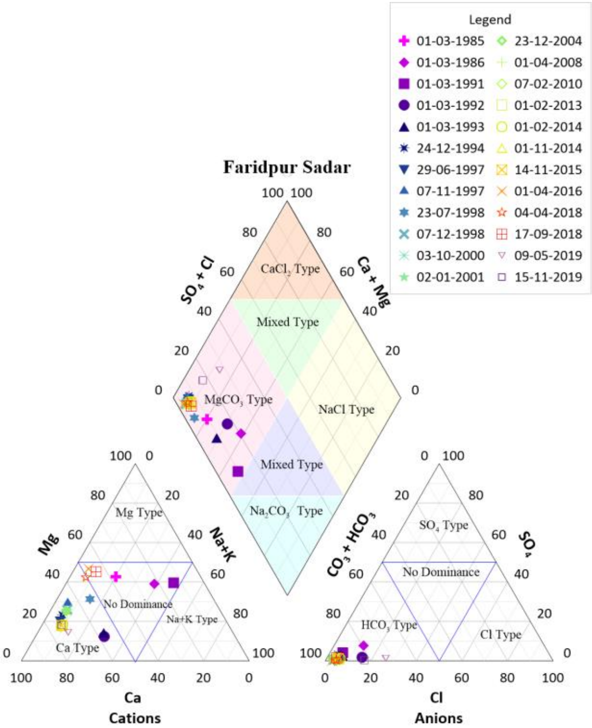


Fig. 6 Piper Diagram

In terms of cations, there is numerous changes in groundwater quality along with time series. Faridpur Sadar,Tangail Sadar,Rajbari Sadar, Gopalganj Sadar, Kishoregonj Sadar have same transition of chemical composition in groundwater samples. Initially, the samples were in no dominance zone but along with time change it becomes Calcium type cations with a range of (60-80)% . The other five samples which are collected from Motijheel , Sherpur Sadar,Tangail (madhupur), Textile Mill Tangail, Rajbari (pangsha) have determined same kind of transformation in hydro chemical facies .The chemical compositions have changed between Ca,Mg and No dominance zone. Rest of the samples are in different dominant zone according to periodic change of time.The highest mili Equivalent concentration of Mg is observed in motijheel which is above 80% of total cations and the highest Ca is observed in Rajbari (Pangsha) (90%).

In addition, it is seen that all the water samples are influenced by Ca cation in recent time except Madaripur Sadar and Sherpur Sadar. For Madaripur Sadar the water constituents become Na+K (90%) types Cations and for Sherpur ,the samples came to fall in no dominance zone. Water hardness is largely induced by the presence of cations such as calcium and magnesium, as well as anions such as carbonate, bicarbonate, chloride, and sulfate in the water.

Because of the relative insolubility of the rock composition, groundwater traveling through igneous rocks dissolves relatively modest amounts of mineral materials.

Table 3 Piper Diagram Summary Table

Station Name	Cations	Anions	Diamond
Faridpur Sadar	No,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Gazipur (Sreepur)	Na+K,Mg,No,Ca	HCO_3 (High)	Mix,Ca-Mg-HCO_3
Gopalganj Kashiani	Na+K,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Gopalganj Sadar	No,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Kishoregonj Sadar	No,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Kishoreganj Bhairab	No,Na+K,Mg,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Madaripur Sadar	Na+K	HCO_3,Cl	Mix,Na-K-So_4
Mohammadpur	Na+K,Mg,Ca	HCO_3 (High)	Mix,Ca-Mg-HCO_2
Motijheel	Ca,No,Mg,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Munshiganj Sreenagar	Na+k,No,Mg,Ca	HCO_3 (High),Cl	Ca-Mg-HCO_3
Narsingdi Sadar	Na+k,No,Ca	HCO_3 (High)	Mix,Ca-Mg-HCO_5
Rajbari	NO,Mg,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Rajbari Sadar	No,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Sherpur Sadar	No,Ca,No	HCO_3 (High)	Ca-Mg-HCO_3
Tangail	No,Mg,Ca	HCO_3 (High)	Ca-Mg-HCO_3
Tangail Sadar	No,Ca	HCO_3 (High),No	Ca-Mg-HCO_3
Mirzapur	Na+k,No,Mg,Ca	No, HCO_3 (High)	Na-K,Ca-Mg-HCO_4
Textile Mill Tangail	Ca,NoCa	HCO_3 (High)	Ca-Mg-HCO_3

4.3 Correlation of the Parameters

Pearson's correlation matrix analysis is a valuable technique for determining the sources and relationships between hydrogeochemical data. The matrix identifies the detailed examination of each parameter separately and their impacts on the process of hydrochemistry.

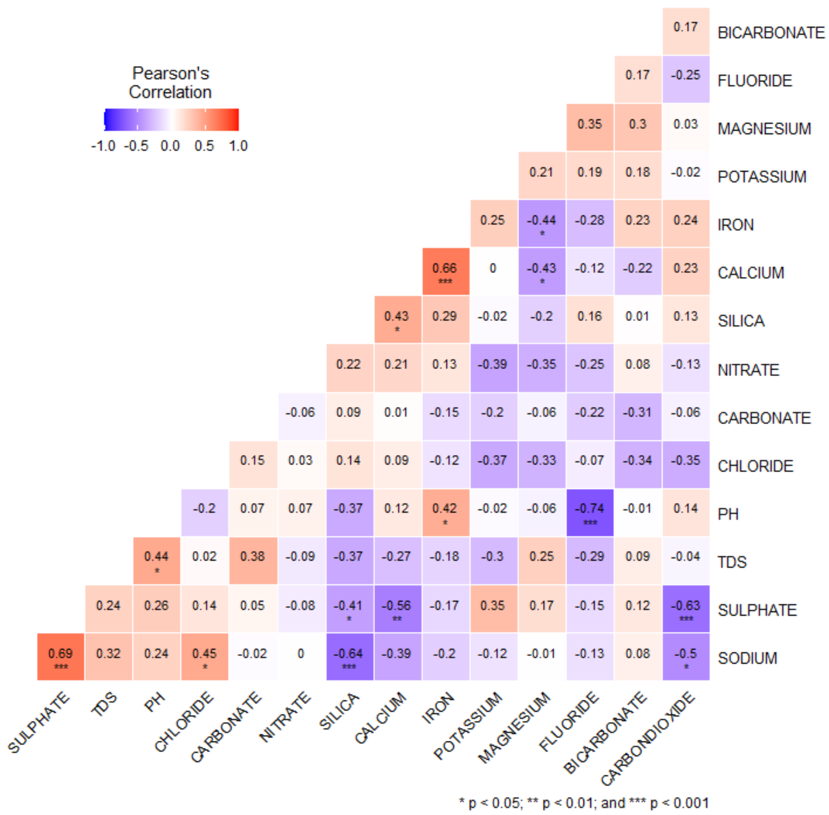


Fig. 7 Pearson's Co-Relation Matrix

Pearson test was used to explore the relationship between comparable factors of 15 groundwater quality at 18 distinct sites in Dhaka division. In the study, there are many strong co relations have been identified which indicating that those parameters have close association with each other. Results also demonstrate that there is significant correlation between Na & SO_4 in Faridpur Sadar (0.69), Mohammadpur (0.92), Narsingdi Sadar (0.72), Rajbari Pangsha (0.7), Tangail Sadar (0.69). On the other hand ,Mg & SO_4 have a notable co relation that have been observed Madaripur Sadar (0.82). These relations concluding that the stations have permanent total hardness which could possibly bring high complexities in chemical reaction inside a groundwater. Sulfate occurs naturally in water as a result of gypsum and other common minerals leaching. The discharge of industrial and household sewage tends to increase its concentration (WHO 1999). This is mainly due to the depth of the water in contact with the rock surface aquifer. The principal sources of calcium and magnesium in most of the groundwater samples are detrital minerals such as plagioclase feldspar, pyroxene, amphibole and garnet (Hounslow 1995). Besides, it is also seen in Kishorganj Sadar and Tangail Mirzapur have increasing correlation of temporary hardness between Na & CO_3 (0.74) and HCO_3 & Na (0.72) respectively. Another severe problem that is observed in KIshorganj Bhairab(0.77), Munshiganj Sreenagar (0.66), Narsingdi Sadar (0.77), Sherpur Sadar (0.88) as there is strong positive co relation between Na & Cl. In this case if Na & Cl increase simultaneously then the salinity of the groundwater will be increased, thus implying the effect on both agriculture field and human health. The relationships clearly highlight the primary factors influencing groundwater salinity and its inclination to follow a similar pattern. It also suggests the potential of the confluence of two groundwater sources with differing end-member compositions, such as fresh and salty, and which are known to be impacted by the presence of saline matrices. The reason behind this strong correlation may because of saline residue seeping from soil, although the effect of ordinary human activities and meteorological conditions may also be factors. The majority of the water samples revealed detectable levels of chlorine. Large quantities of Cl, when combined with Ca and Mg, increase the corrosiveness of water. TDS has a high association with sodium , showing the relevance of halite in the aquifer's overall ionic composition. The presence of TDS above this limit in groundwater would cause undesirable taste and gastrointestinal irritation (Selvakumar et al. 2014). There are some parameters shows highly negative values which determines that these variables have inverse relation. The highly negative correlations are shown in Tabel No. 4. Despite being an effective technique, correlation analysis could only provide broad insights into water-rock interactions. A full examination, such as aquifer mineralogy, is required to provide more comprehensive and reliable data concerning these complex systems of water-rock interactions. According to correlation analysis, the groundwater chemistry in the studied region is influenced by both natural and human activities. The high correlation between some of the ions shows that rock weathering and cation exchange are dominant.

Table 4 Pearson's Co Relation Matrix Summary Table

No	Station Name	High Positive Co-Relation	High Negative Co-Relation	No relation
1	**Faridpur Sadar**	Na & SO_4 0.69	PH & F 0.74	Ca & K, Na & NO_2
2	**Gazipur (Sreepur)**	Cl & CO_3).65	Na & Si 0.75	SO_4 & K
3	**Gopalganj Kashiani**	Ca & Fe (0.65), TDS & HCO_3 (0.65)	-	-
4	**Gopalganj Sadar**	TDS & HCO_3 (0.75), Ca & CO_2 ().85	Ca & Na (0.65)	CO_2 & PH,CO_3 & NO_2
5	**Kishoregonj Sadar**	Na & CO_3 (0.74)	Ca & Na (0.66)	TDS & CO_3
6	**Kishoreganj Bhairab**	Na & Cl (0.77)	Ca & Na (0.75)	K & F,PH & SO_4
7	**Madaripur Sadar**	Mg & SO_4 (0.82)		SO_4 & PH
8	**Mohammadpur**	Na & SO_4 (0.92), TDS & F (0.82), TDS & HCO_3 (0.69), HCO_3 & CO_2 (0.69)	Na & CO2 (0.65)	TDS & Na
9	**Motijheel**	Cl & SO_4 (0.77)		HCO_3 & NO_2, F & Na
10	**Munshiganj Sreenagar**	Na & Cl (0.66)	Mg & Si (0.8)	CO_2 & Cl
11	**Narsingdi Sadar**	Na & Cl (0.77), SO_4 & Na (0.72)	CO_2 & SO_4 (0.67),Si & Mg (0.66)	Na & Fe ,TDS & Mg
12	**Rajbari**	TDS & Cl (0.76), Ca & CO_2 (O.76), SO4 & Cl (0.74), Na & SO_4 (0.7)	-	TDS & SI, TDS & NO_2
13	**Rajbari Sadar**	-	-	HCO3 & K
14	**Sherpur Sadar**	Na & Cl (0.88), TDS & Cl (0.77)	F & Ca (0.67)	Ca & PH,Fe & CO_3 , Mg & K
15	**Tangail**	HCO_3 & Si (0.83)	CO_2 & Na(0.74)	Na & Mg, Si & Cl, Na & K
16	**Tangail Sadar**	Si & CO_2 (0.68), Na & SO_4 (0.69)	Cl & Fe (0.69)	K & F
17	**Mirzapur**	HCO_3 & Na (0.72), HCO_3 & TDS (0.72), TDS & Na (0.73)	Ca & Cl (0.77)	-
18	**Textile Mill Tangail**	Cl & SO_4 (0.88)	NO2 & PH (0.67)	Mg & Fe

5 CONCLUSION

This study illustrates an integrated approach involving time series trend analysis and GIS-based geostatistical modeling in a comprehensive manner by following a standard methodology to associate probable sources of natural and hadrochemical characteristics of groundwater resources in a hard-rock aquifer system of central Bangladesh, Dhaka division. Mann–Kendall, Piper Diagram Spearman Rank Order Correlation, and Sen's slope estimate tests were used to identify and quantify trends in 45-year groundwater quality metrics for 18 locations. A GIS-based groundwater quality mapping was created to distinguish between poor and high groundwater quality zones.

Box and whisker plots revealed that the hardness of groundwater exceeds the allowable limit for the majority of aquifer system locations. The results of Man Kendal and Modified Man Kendal test have classified 18 locations into 2 categories. One is the increasing trend and the other is decreasing. There are some certain stations who have already cross the standard limits of water quality index and also show positive trend in Man Kendal , Modified Man Kendal Test as well. Those stations are in extreme case scenario. For some station some parameter are in standard limit and trend are positive which has a great a chance to cross the standard limit. It decrease the groundwater quality. And negative trend increase groundwater quality.The chemical composition of groundwater demonstrated that numerous processes, such as salinization, water hardness, and alkalinity, regulate water quality. From piper diagram almost every stations have shown $Mg(HCO_3)_2$ type characteristics except Madaripur Sadar. Madaripur Sadar have high probability of increasing Na and Cl ion. Pearson Co relation Co efficeient also confirms the increments of this salt. Besides, Mg and SO_4 have strong co relation almost every stations that indicates the sample have total hardness. On the other hand, The quality of groundwater in Dhaka division is majorly resulted from interaction with alluvial flood plain , dissolution of carbonates or sulphates, and ion exchange between water molecules and clay minerals.

Furthermore, it is worth noting that the primary justification for doing groundwater-quality research in a region with administrative borders, as is the case with this work, is because field data are often readily available at adequate spatial and temporal resolutions. Such locations, which are predicted to be more sensitive to groundwater pollution and exploitation, urgently require scientific research to ensure the long-term management of the area's/essential region's groundwater resources. One of the limitations of this study is that i) The data is not properly consistent and the other one is to continue this study on a larger magnitude, more data should ne needed for the study area. The study's findings will also be valuable to policymakers and decision makers in developing effective groundwater consumption and management strategies for Pliocene aquifer systems in other regions of the world in order to assure a safe and high-quality supply of groundwater.

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7 APPENDIX

Perason Correlatiom

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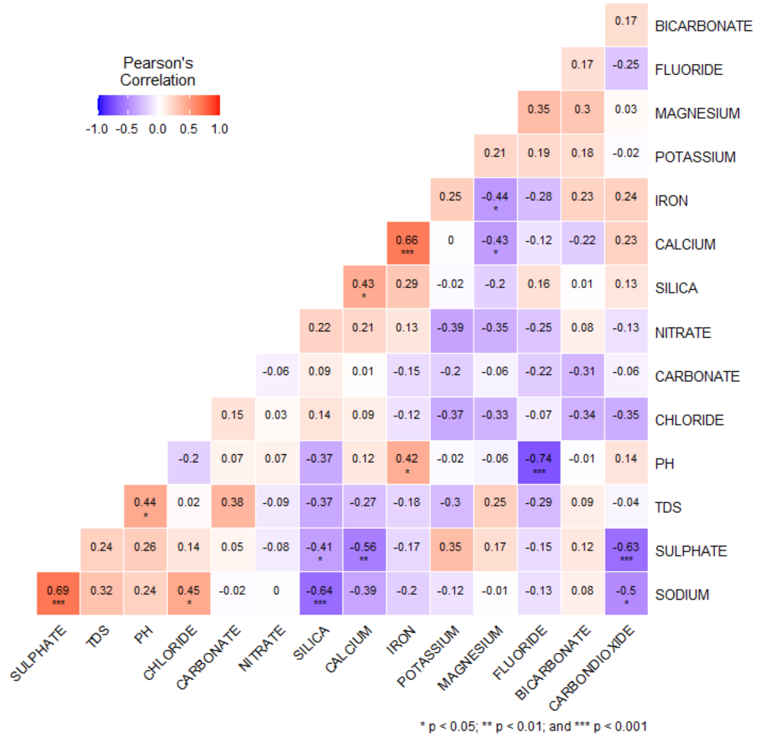

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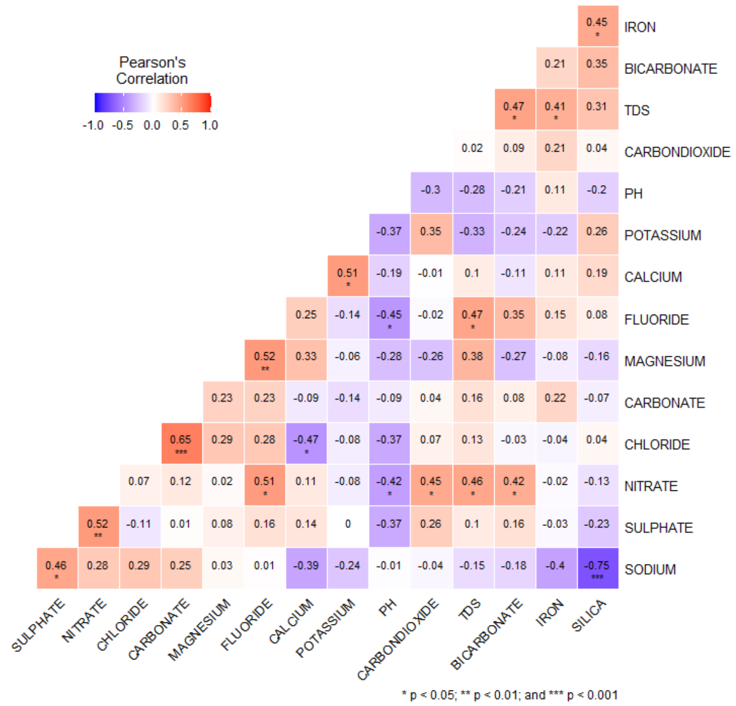

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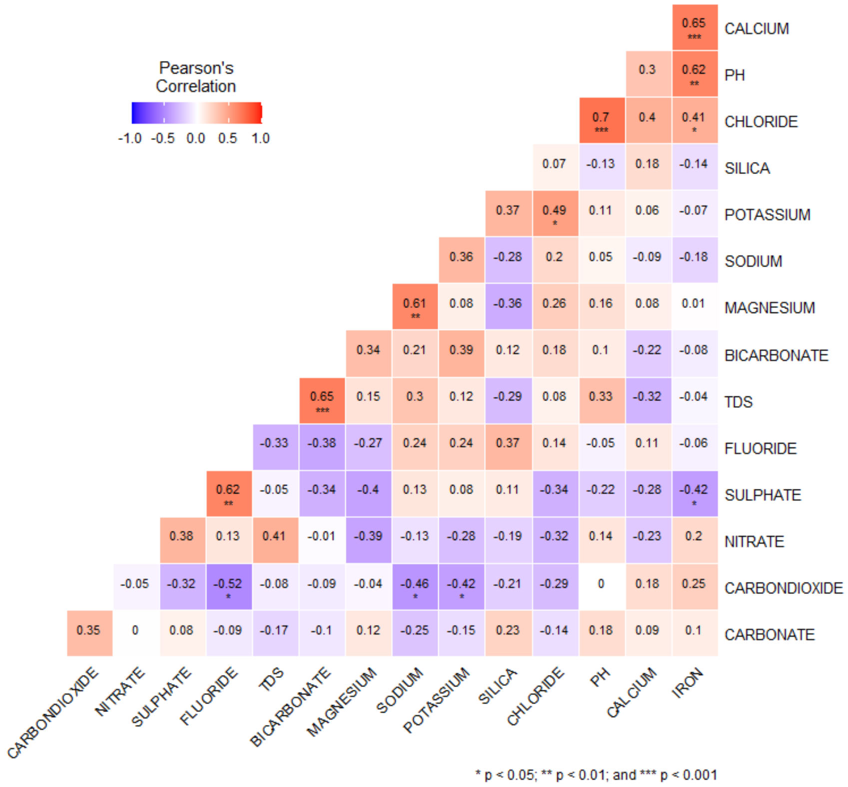

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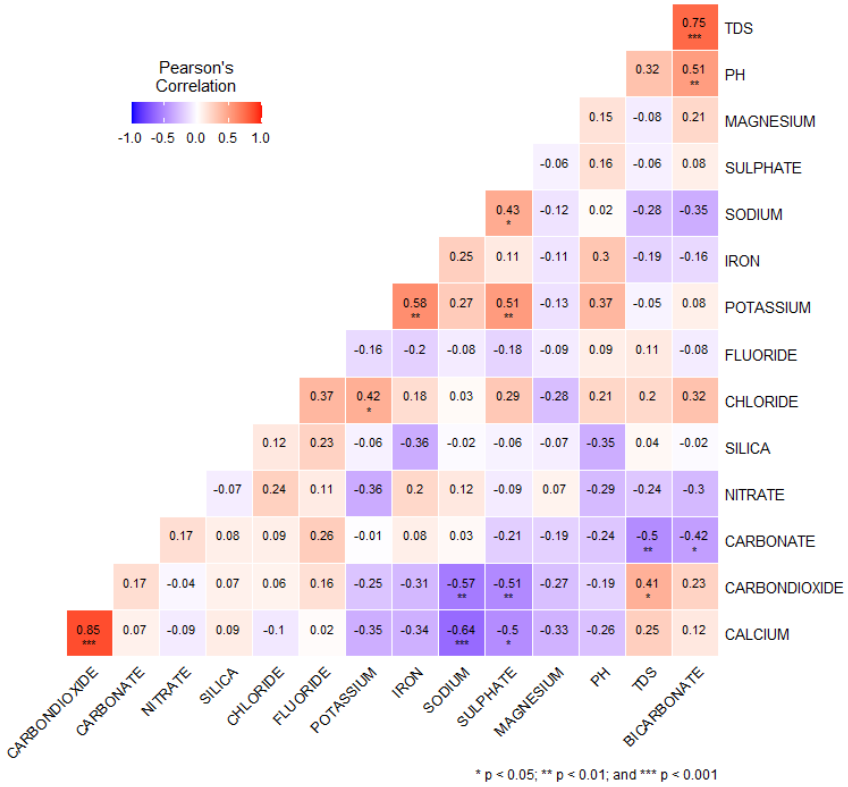

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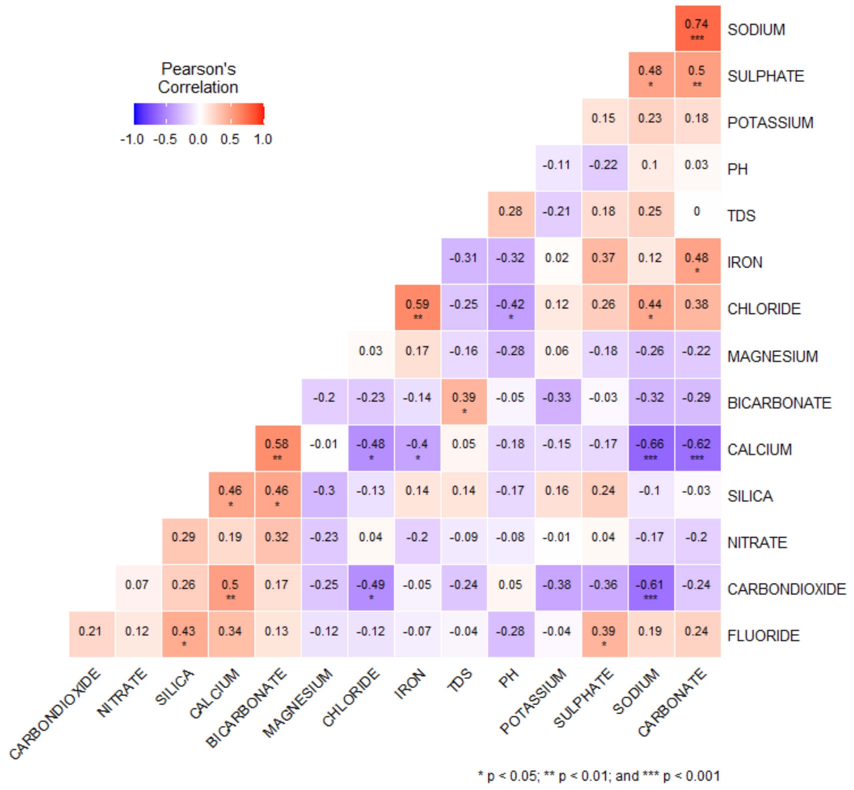

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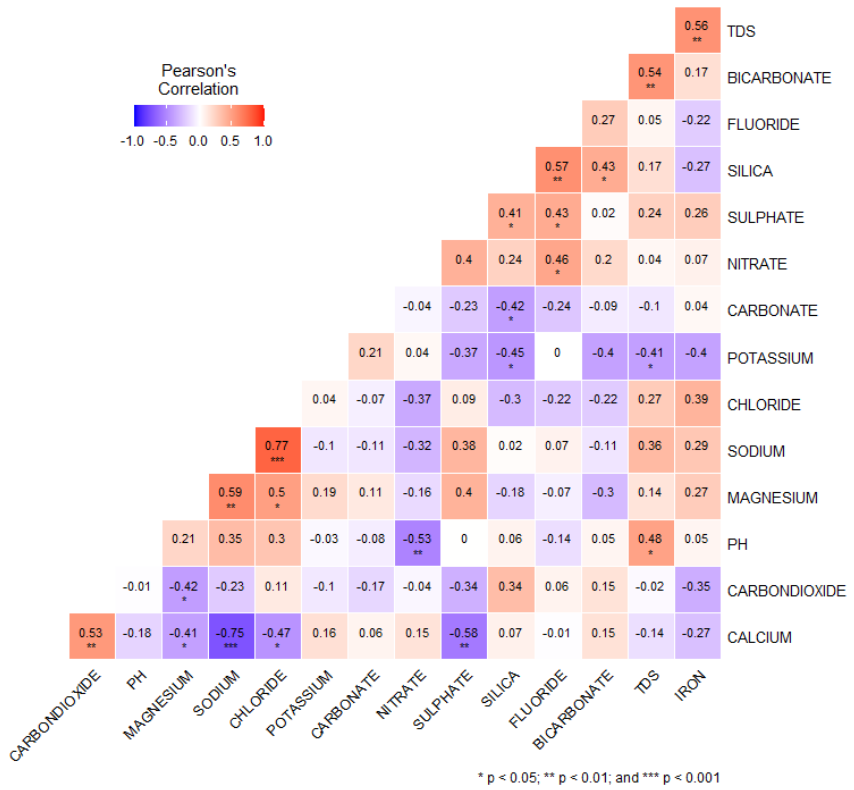

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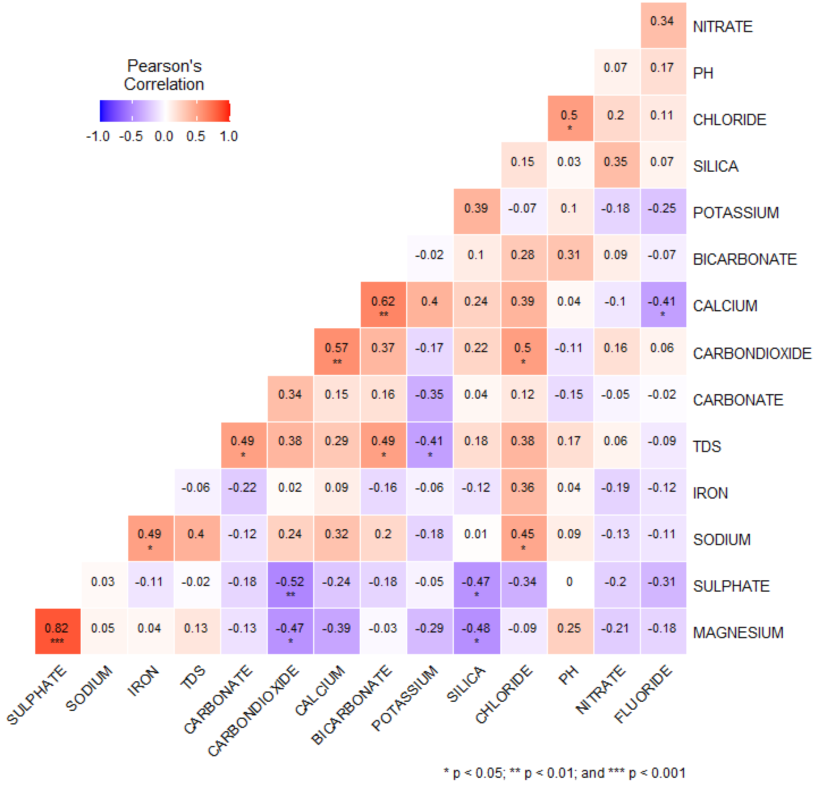

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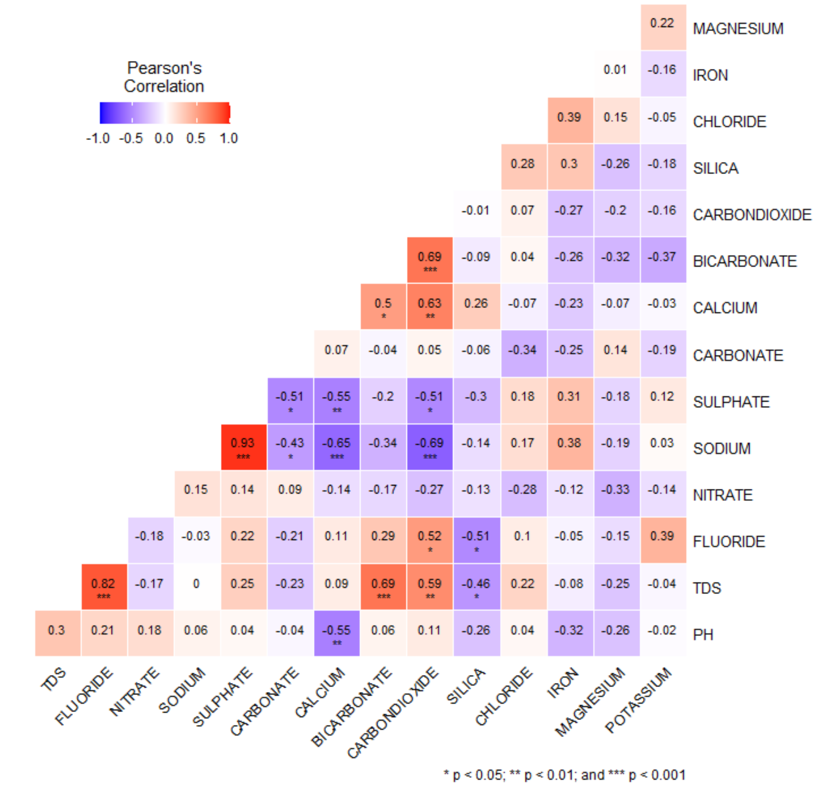

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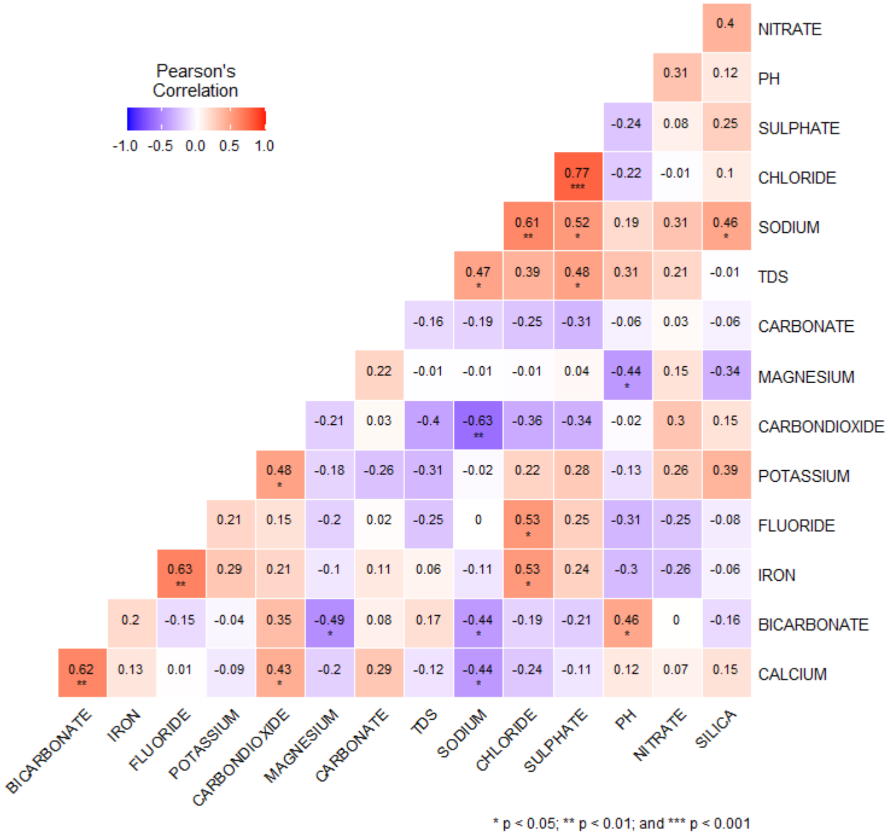

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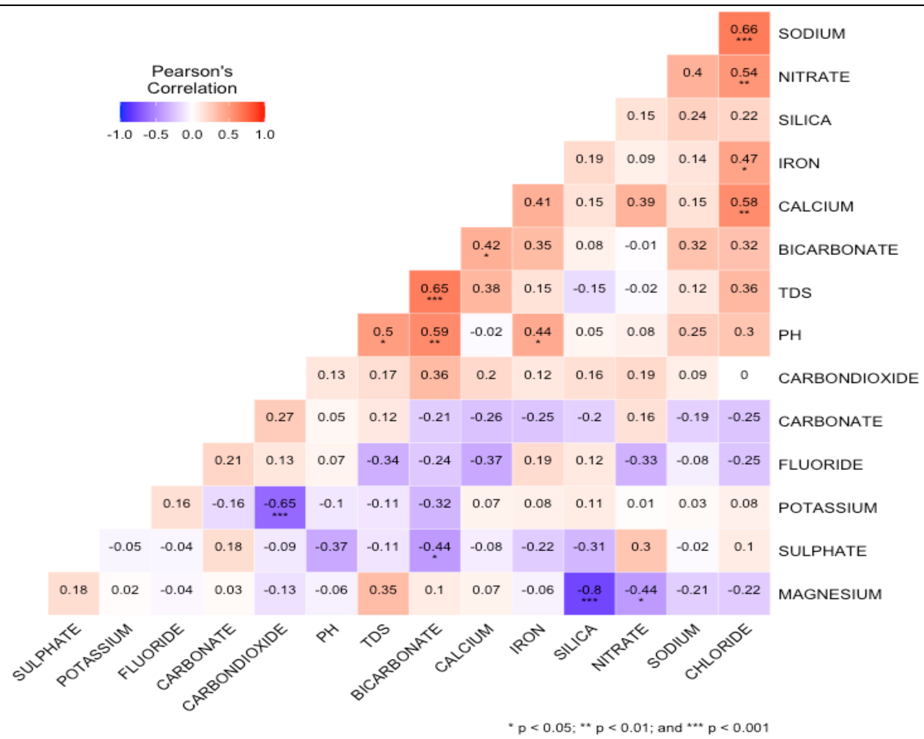

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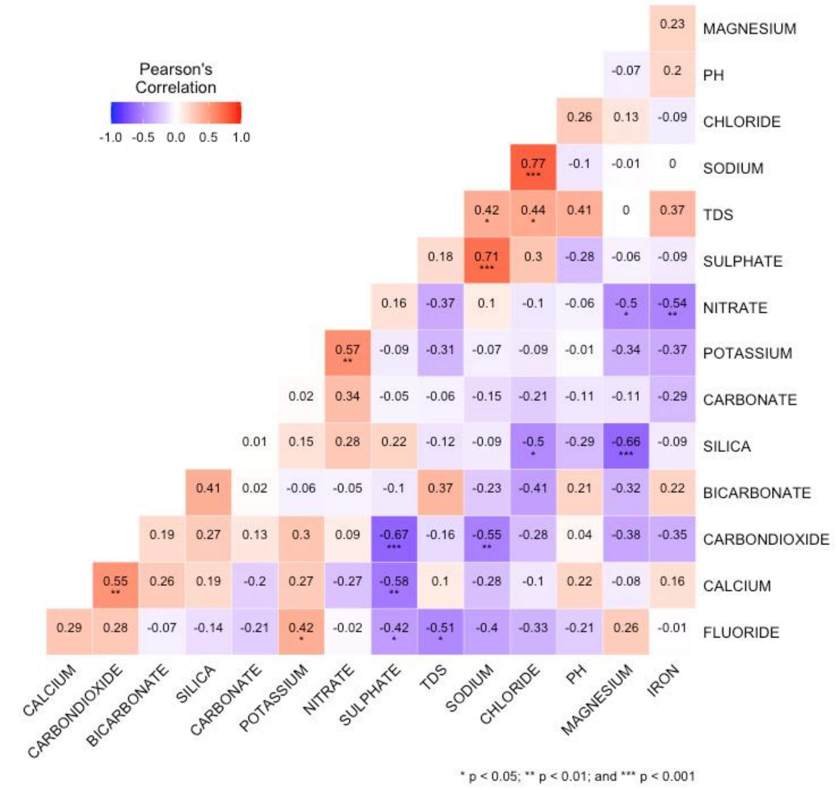

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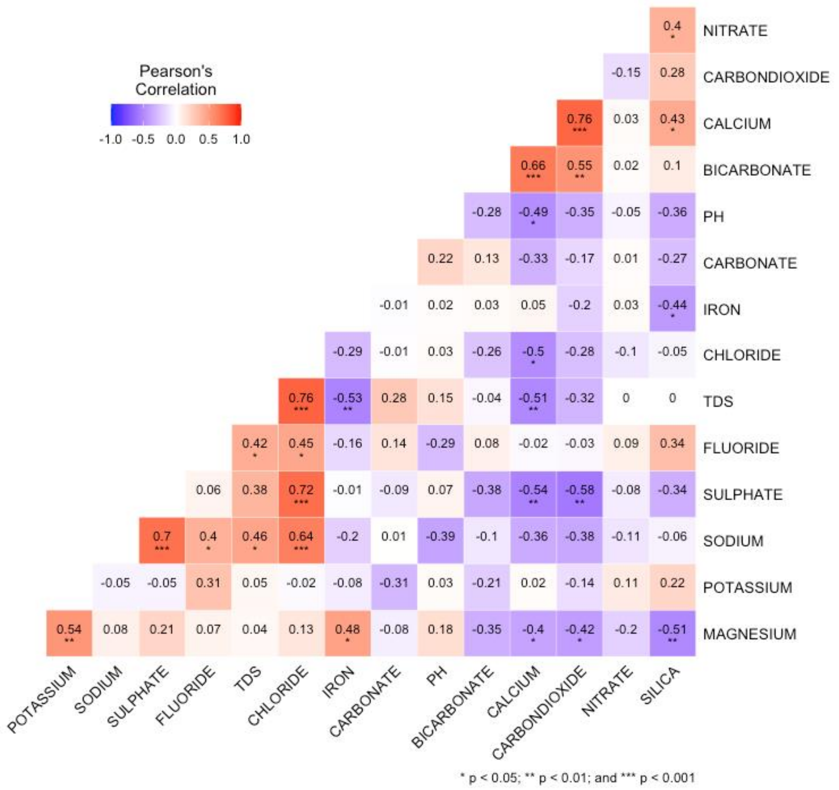

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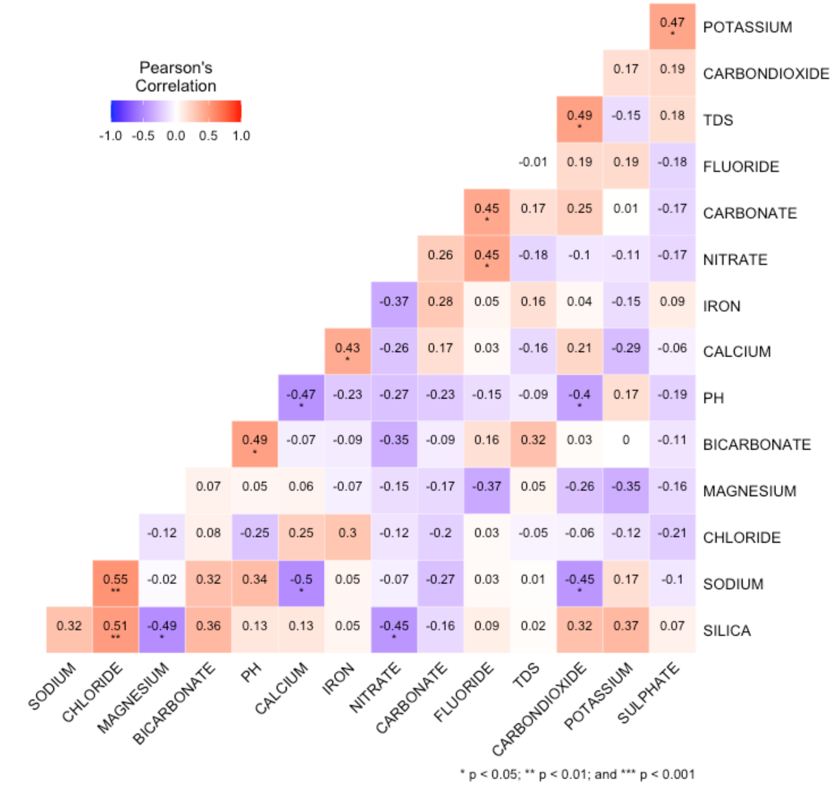

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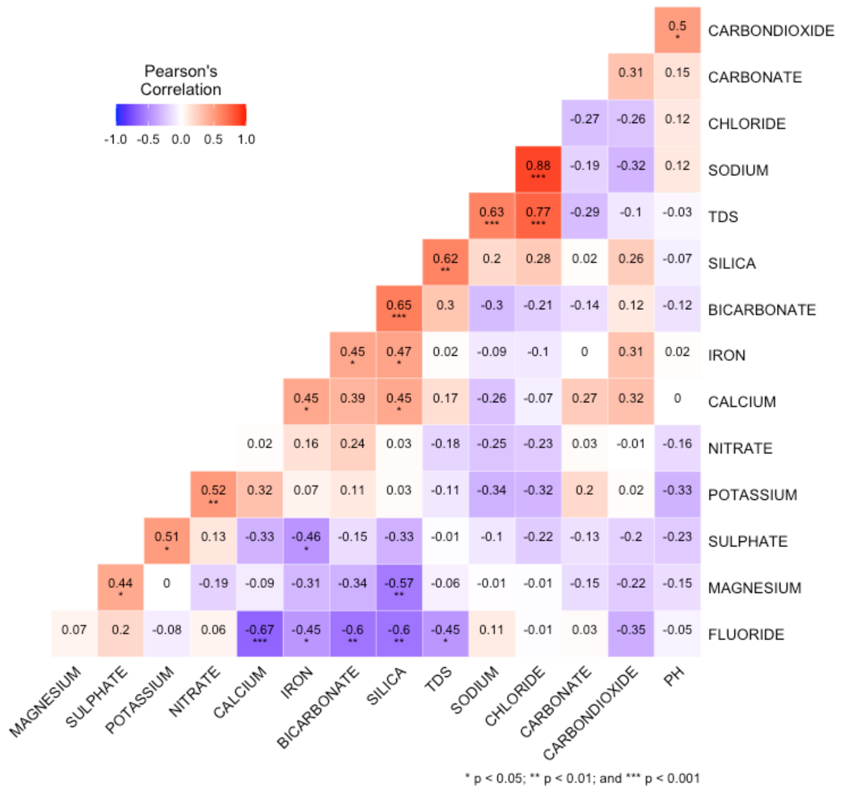

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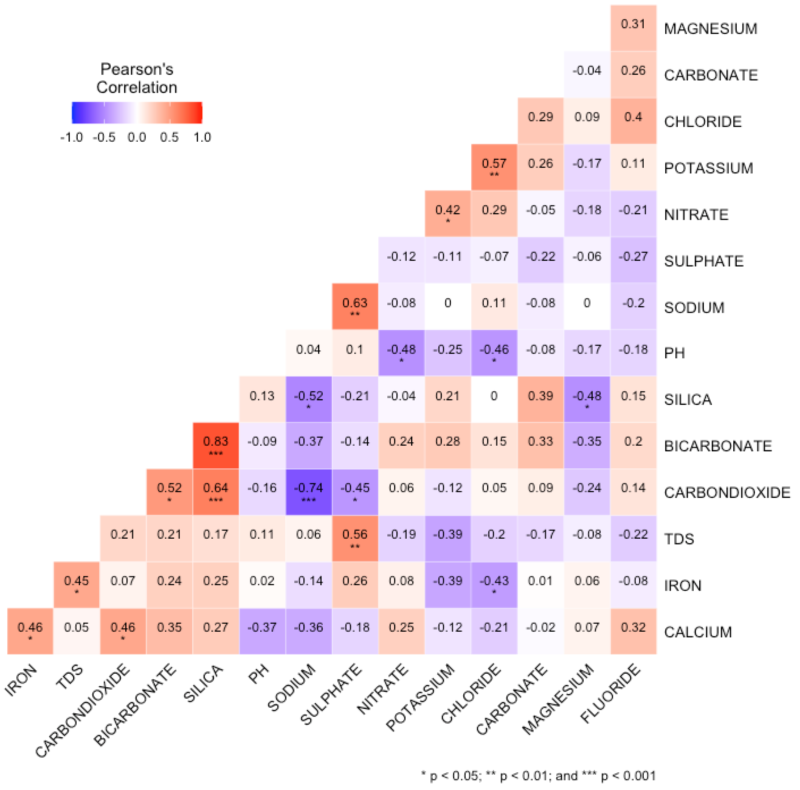

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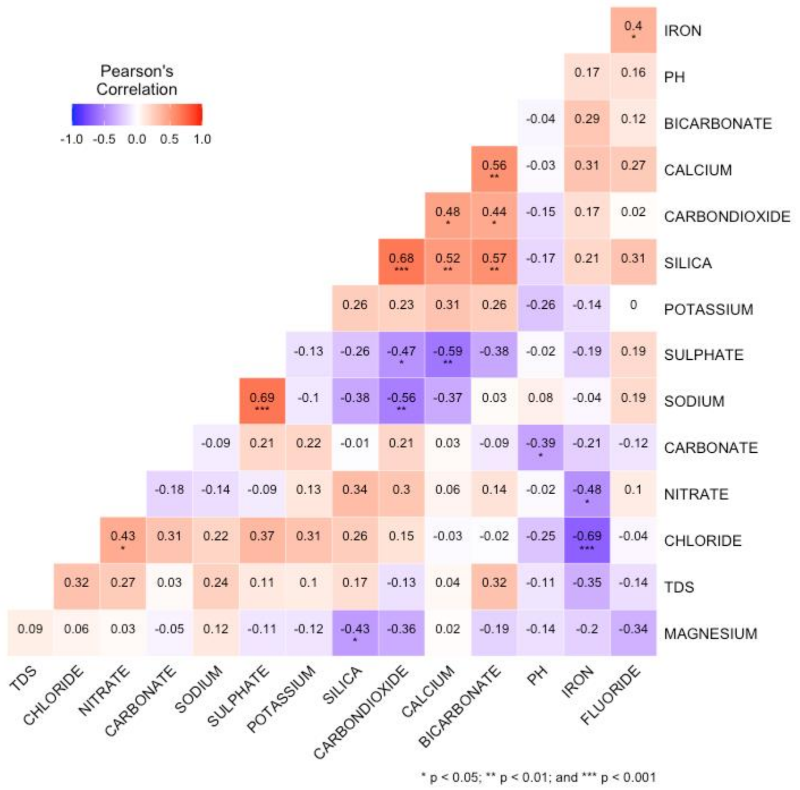

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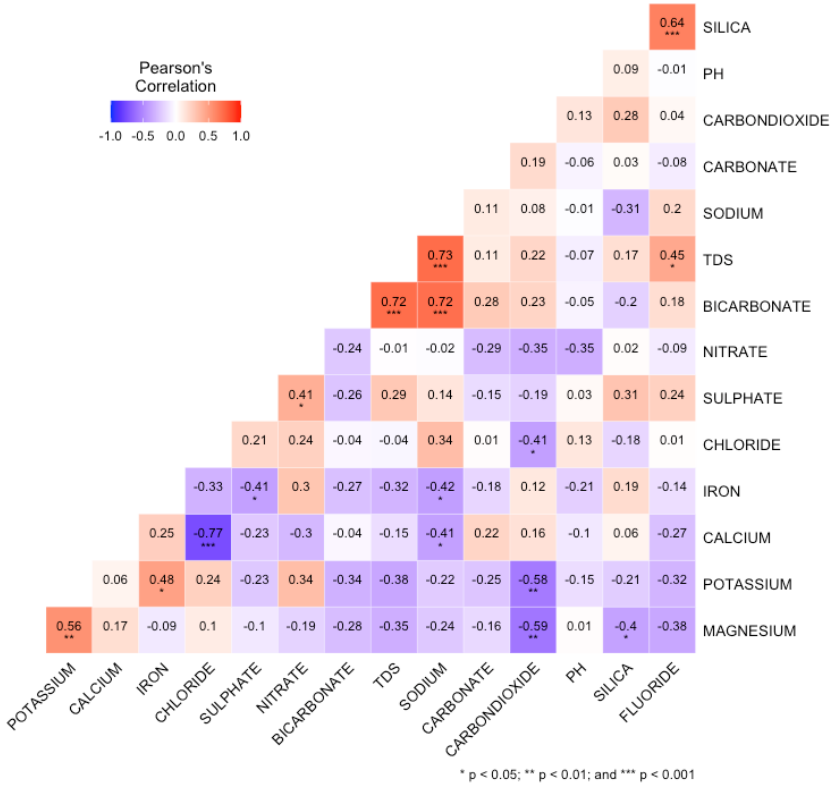

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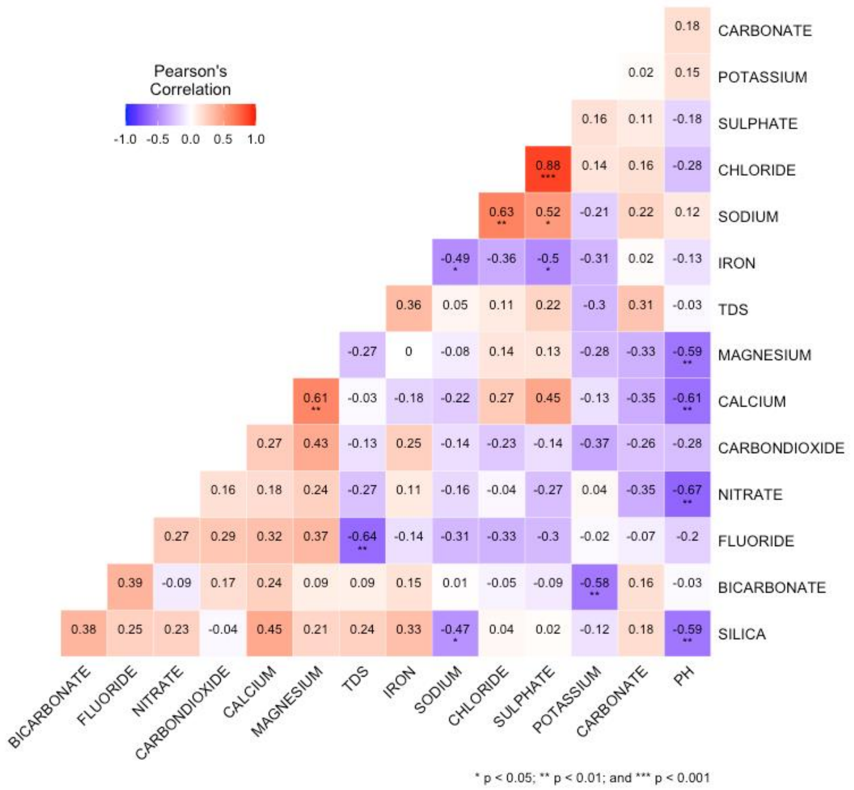
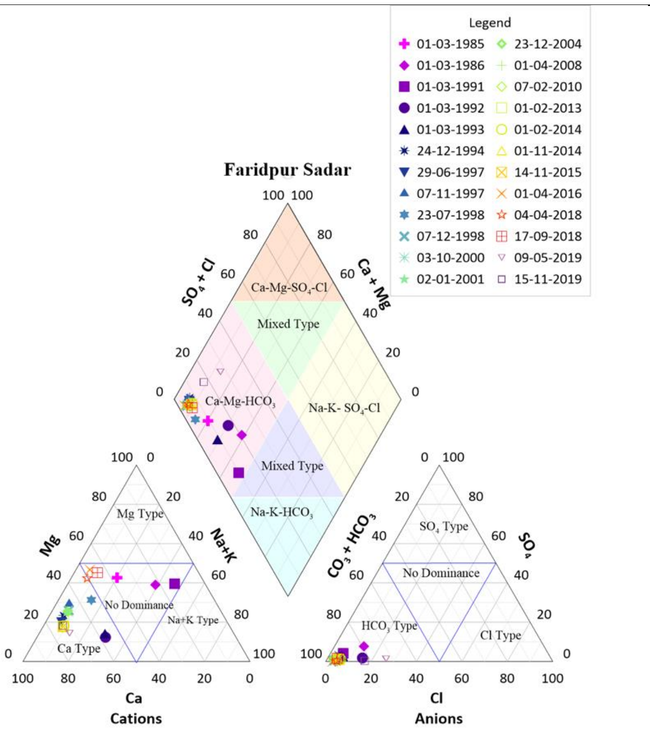


Piper Diagram

Faridpur Sadar



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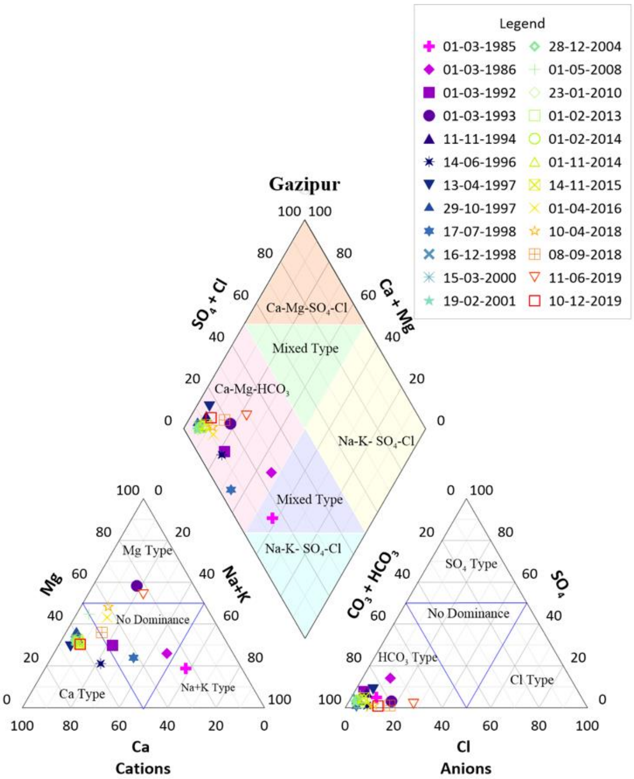

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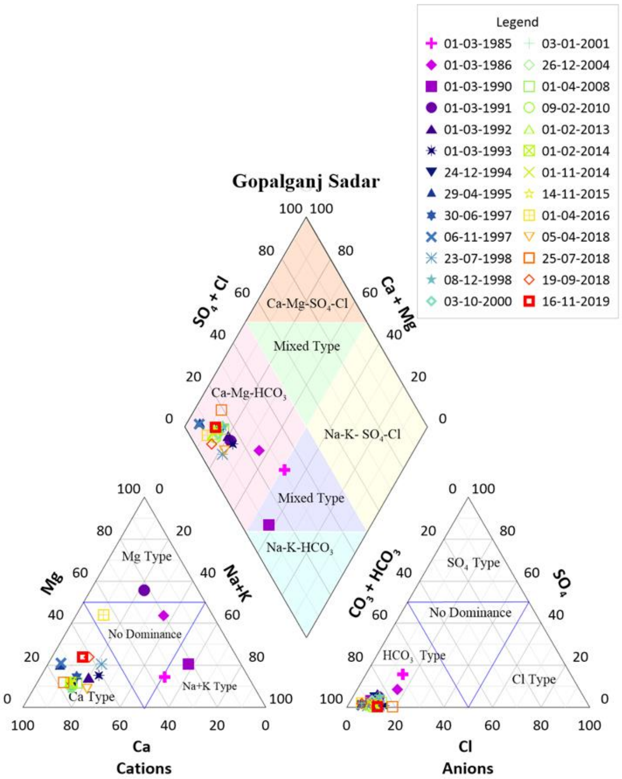

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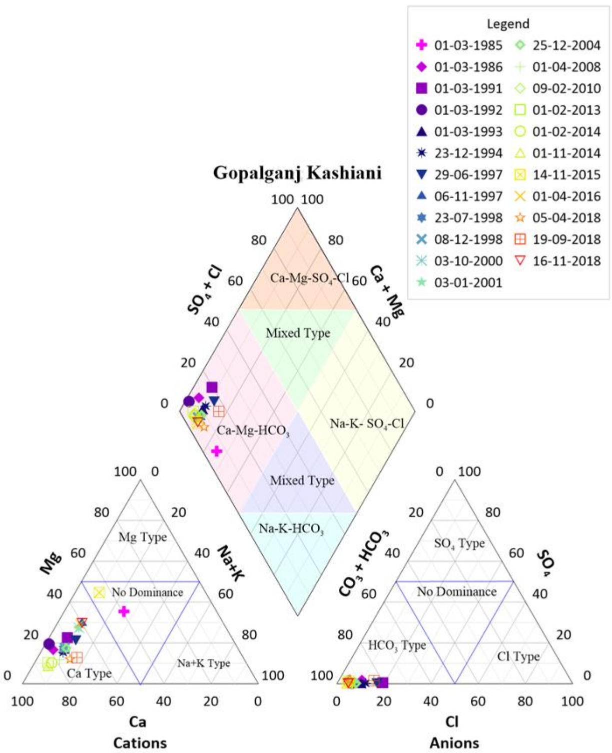

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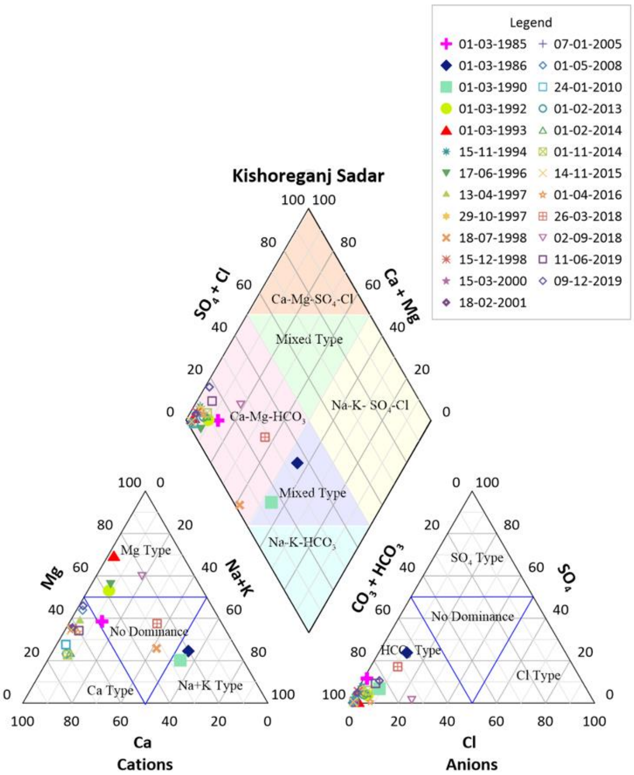

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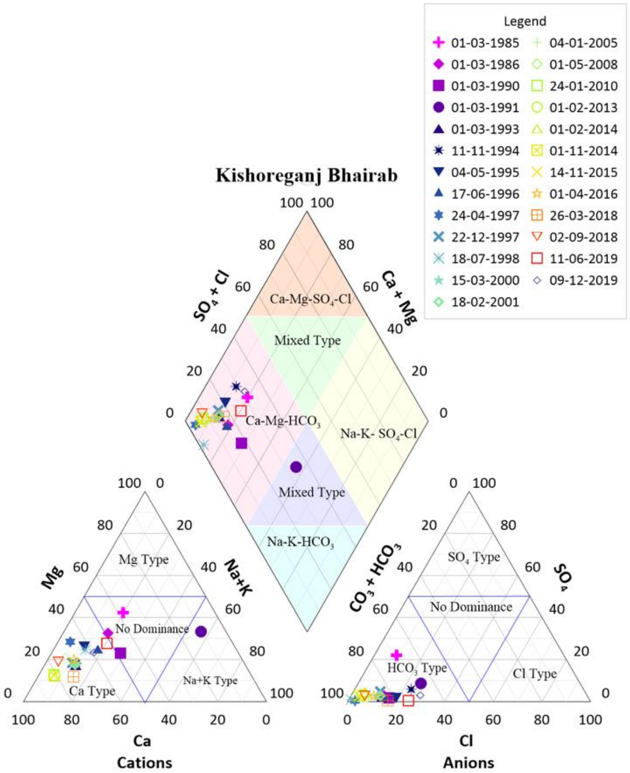

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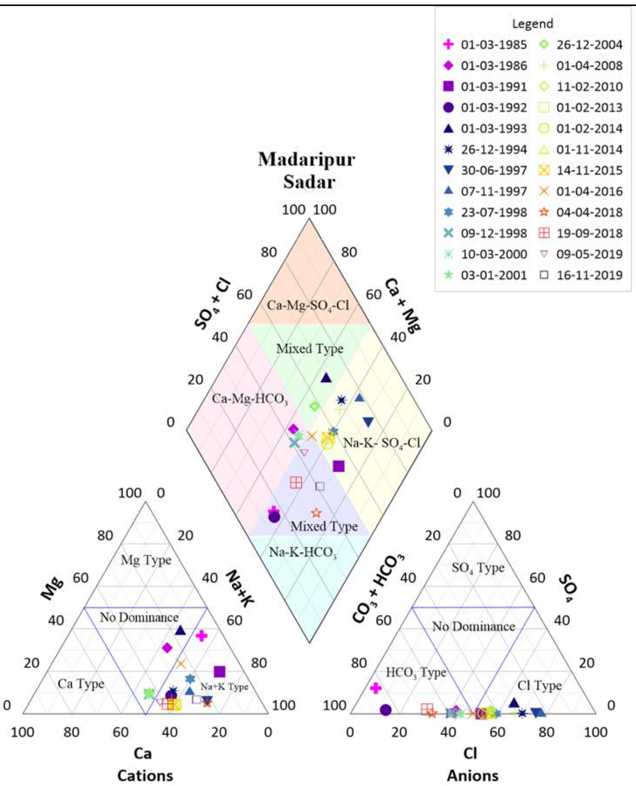

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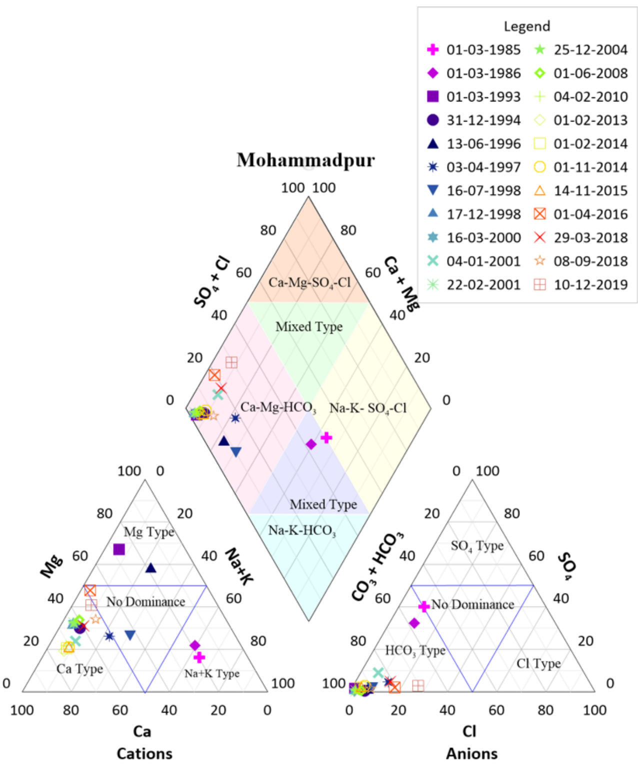

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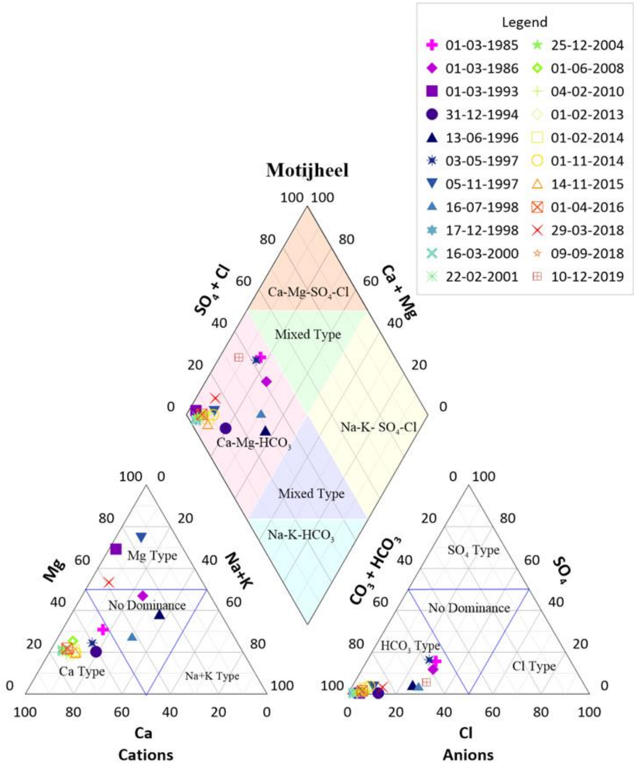

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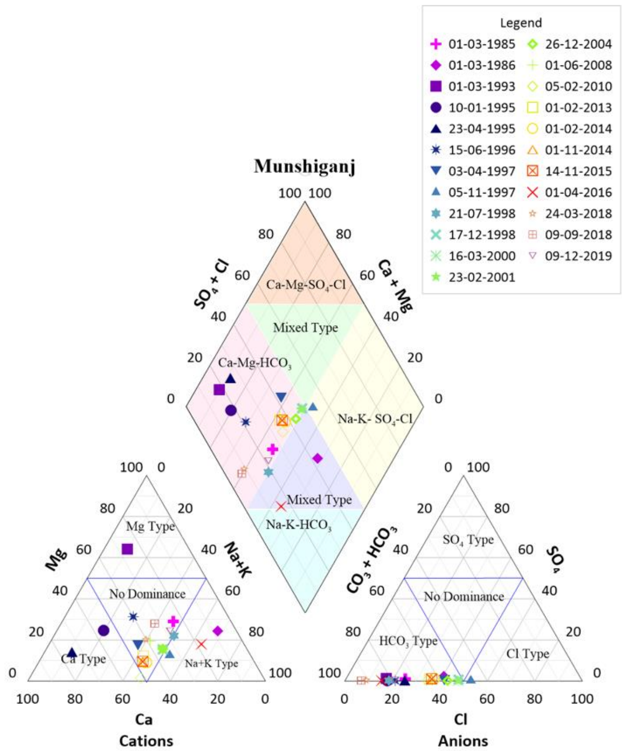

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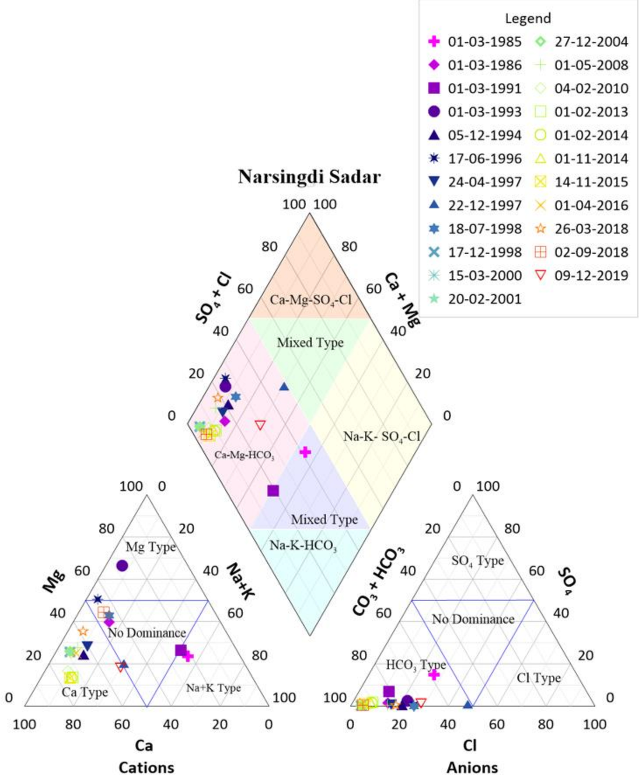

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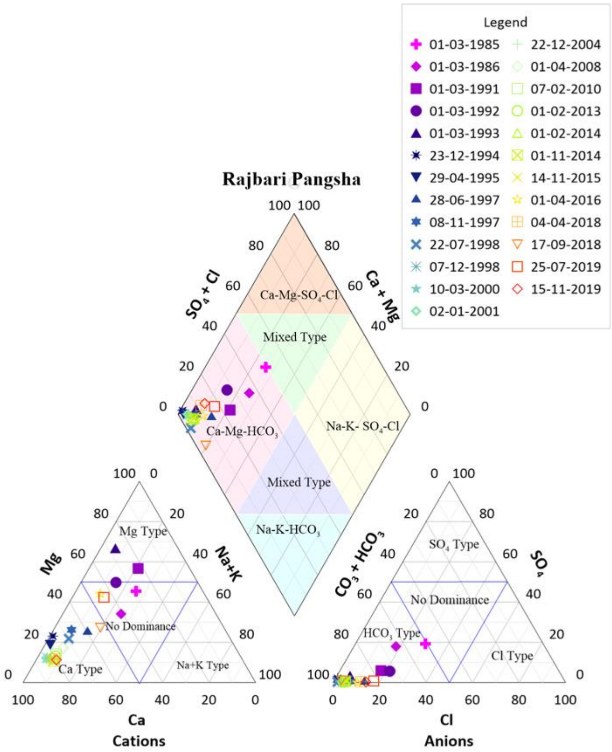

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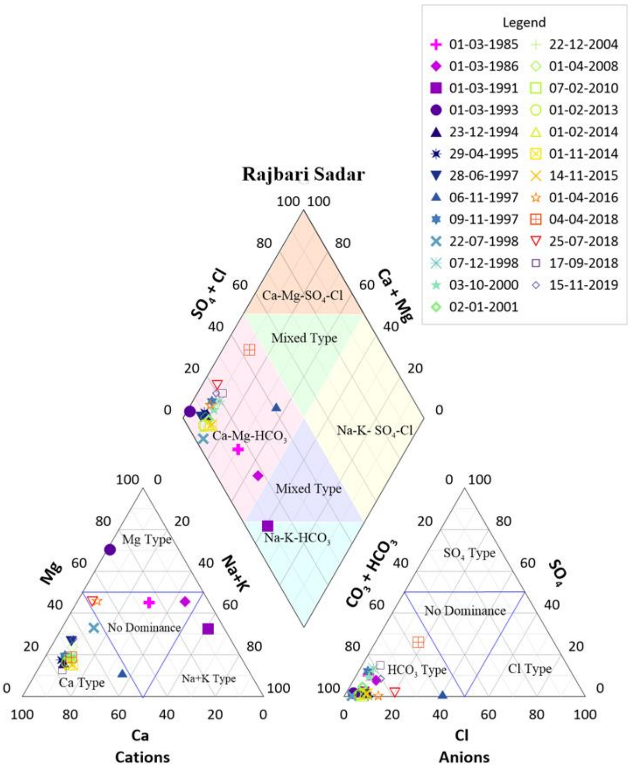

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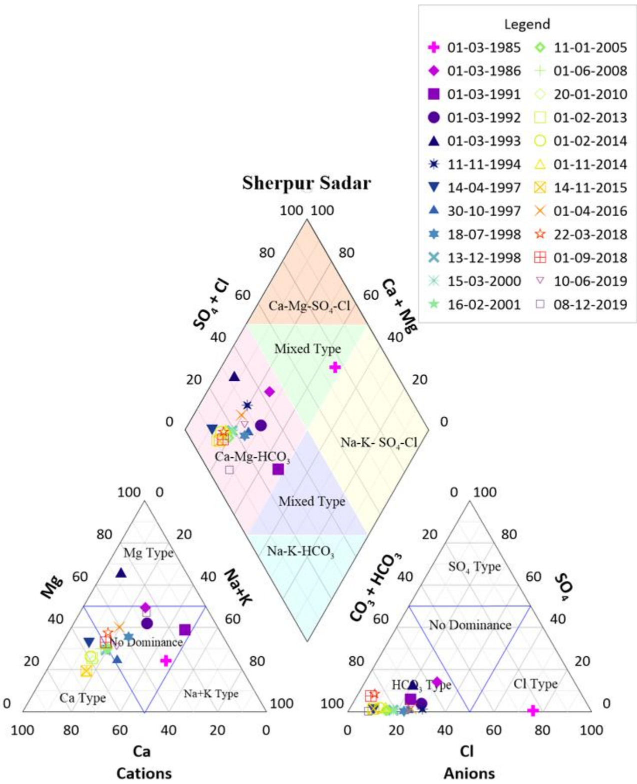

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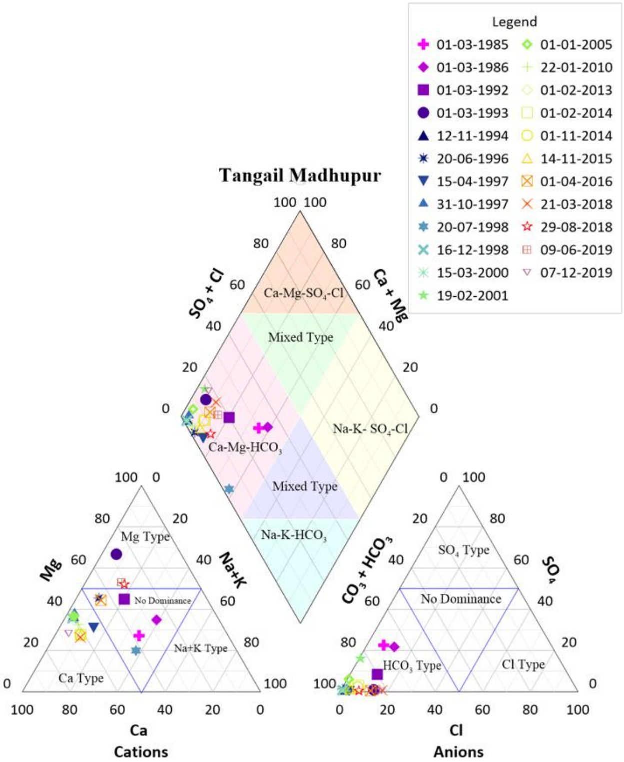

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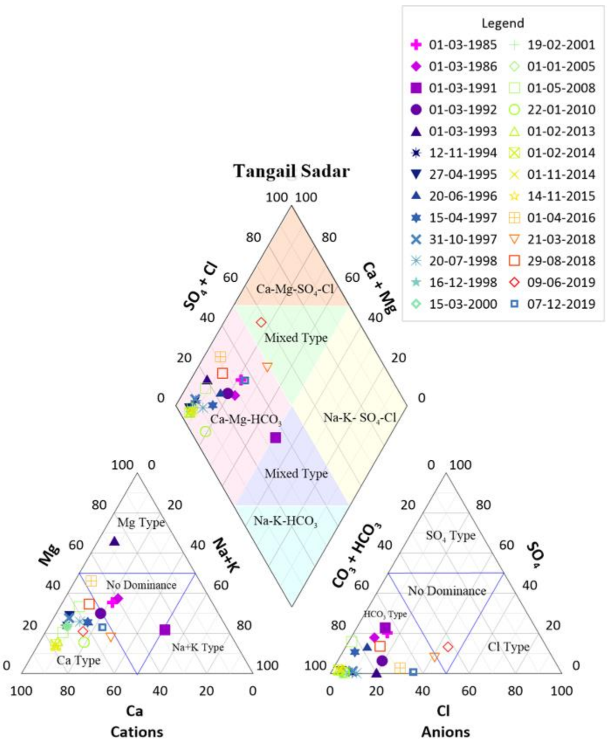

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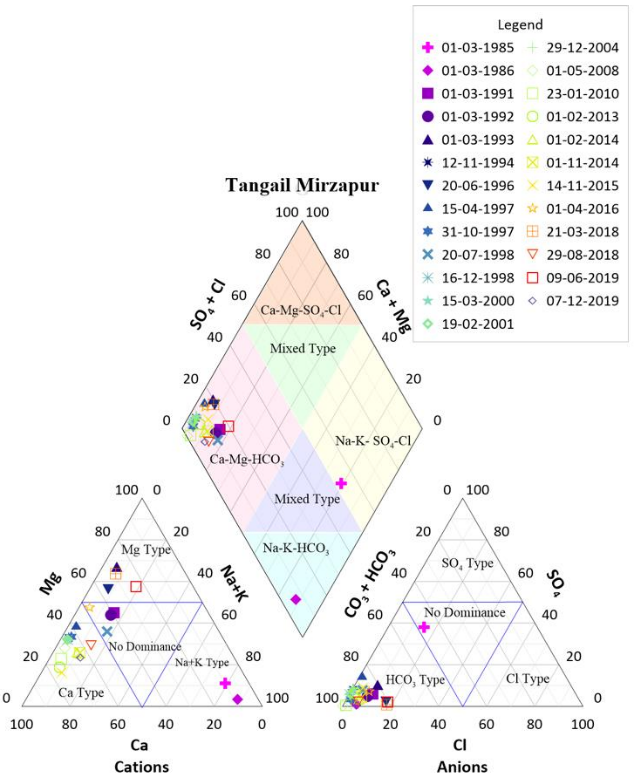

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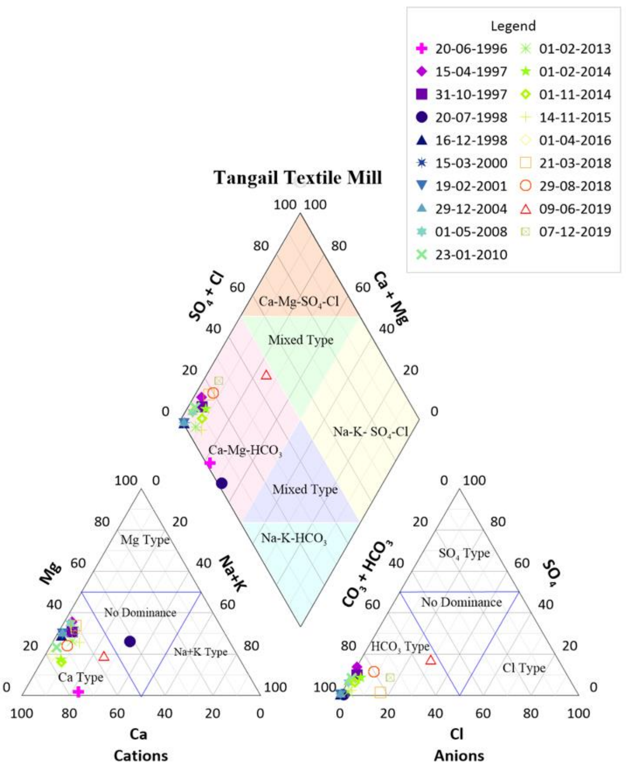

Whisker Plot

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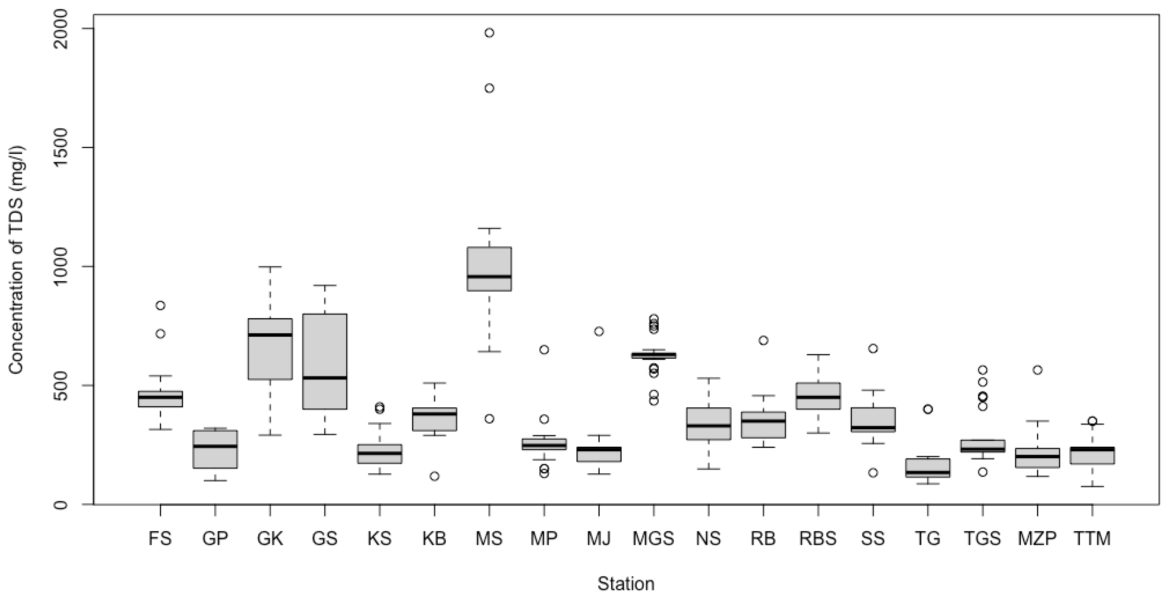

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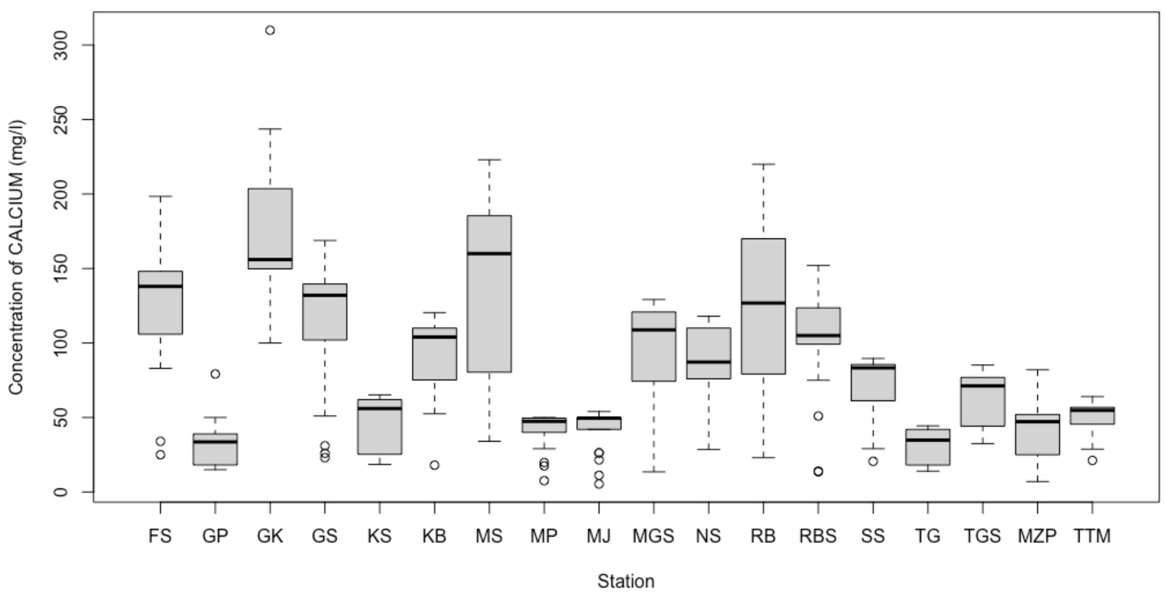

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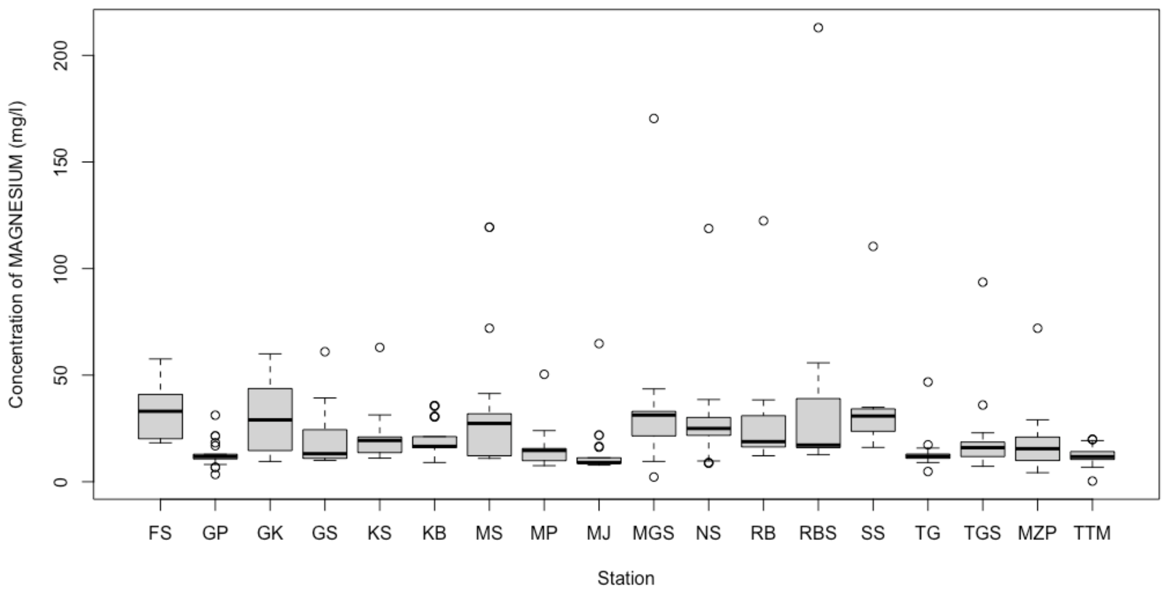

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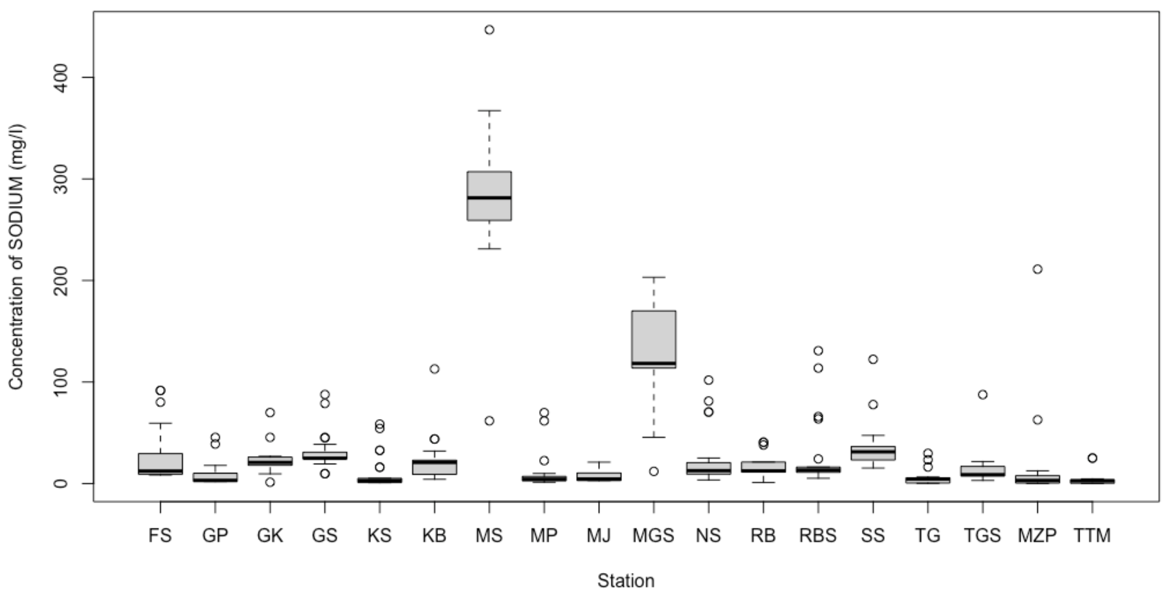

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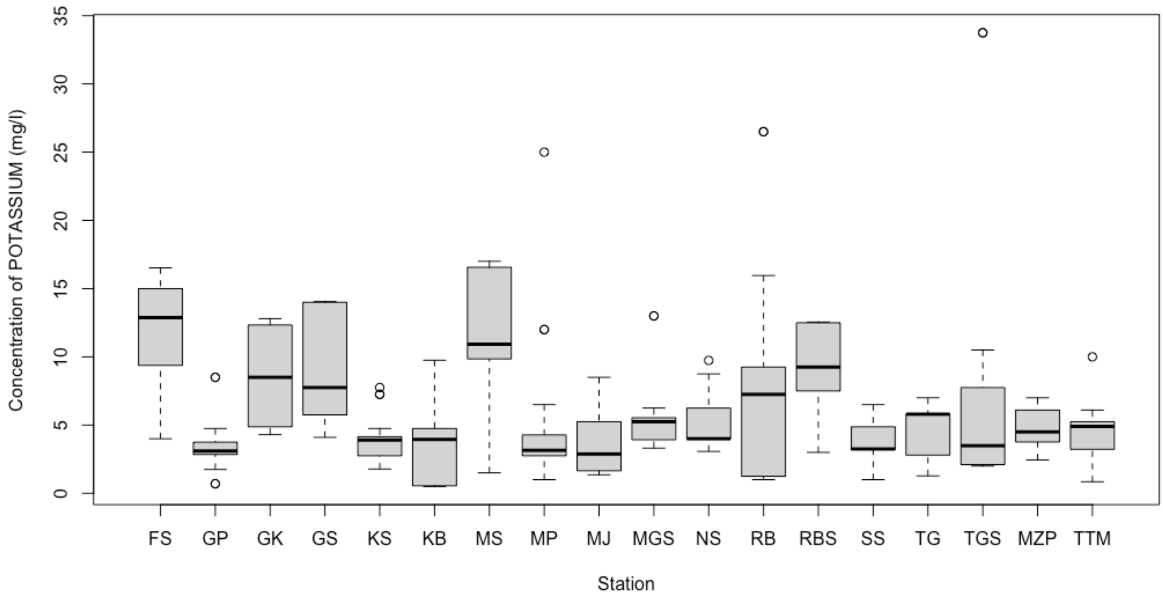

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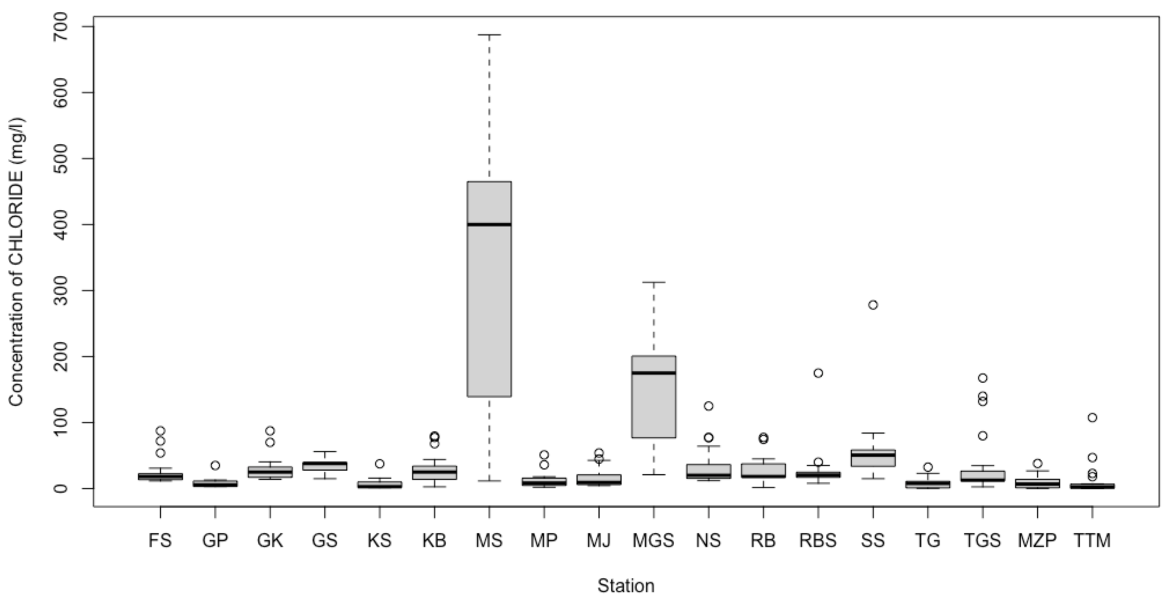

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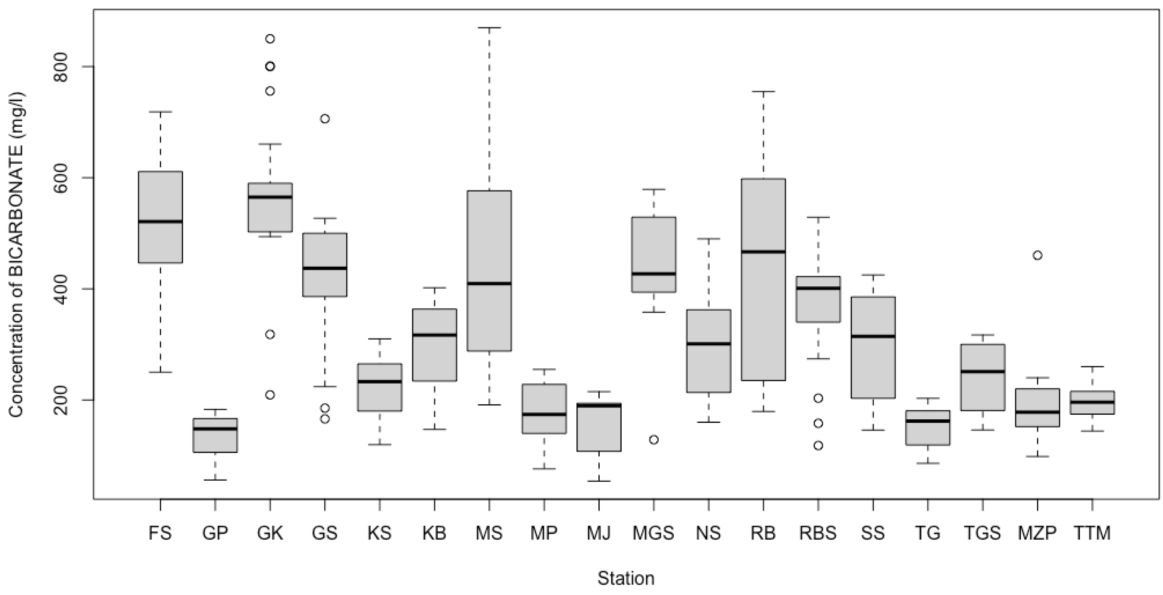

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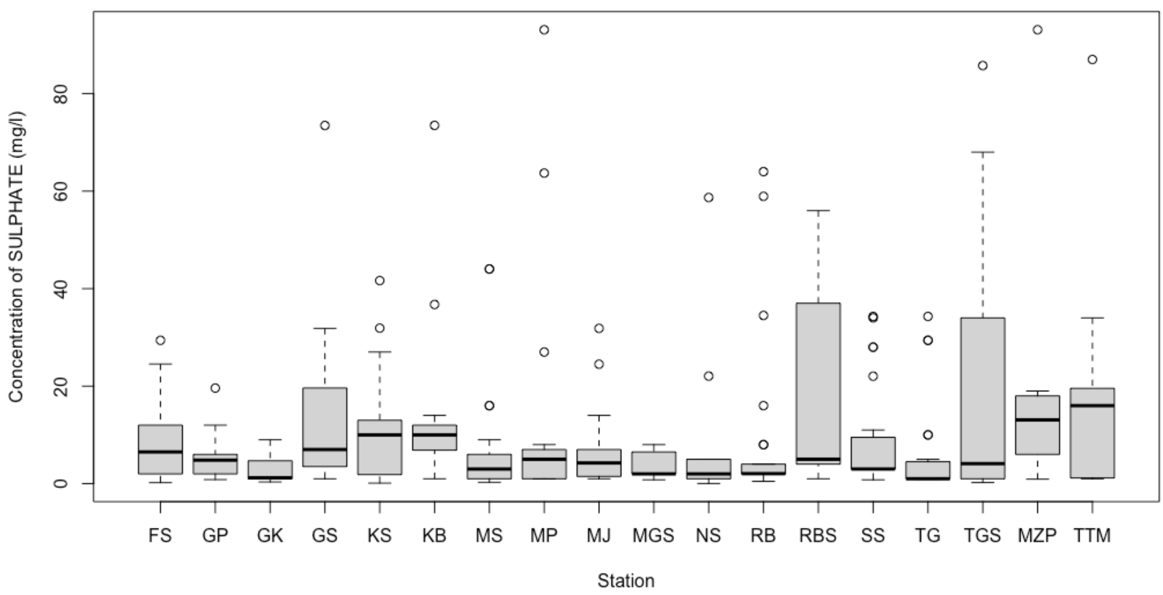

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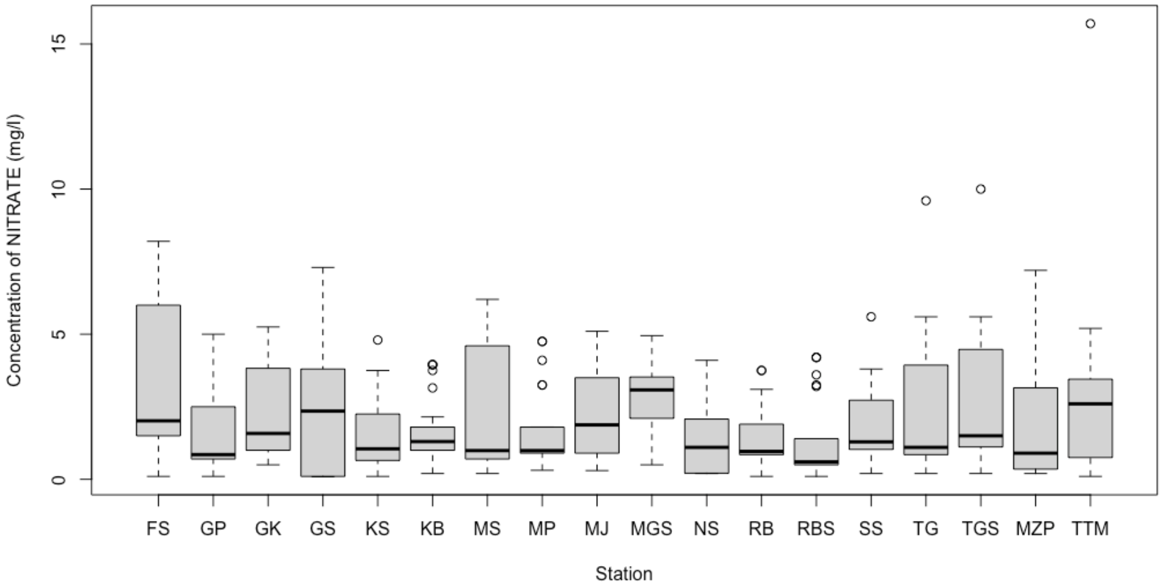

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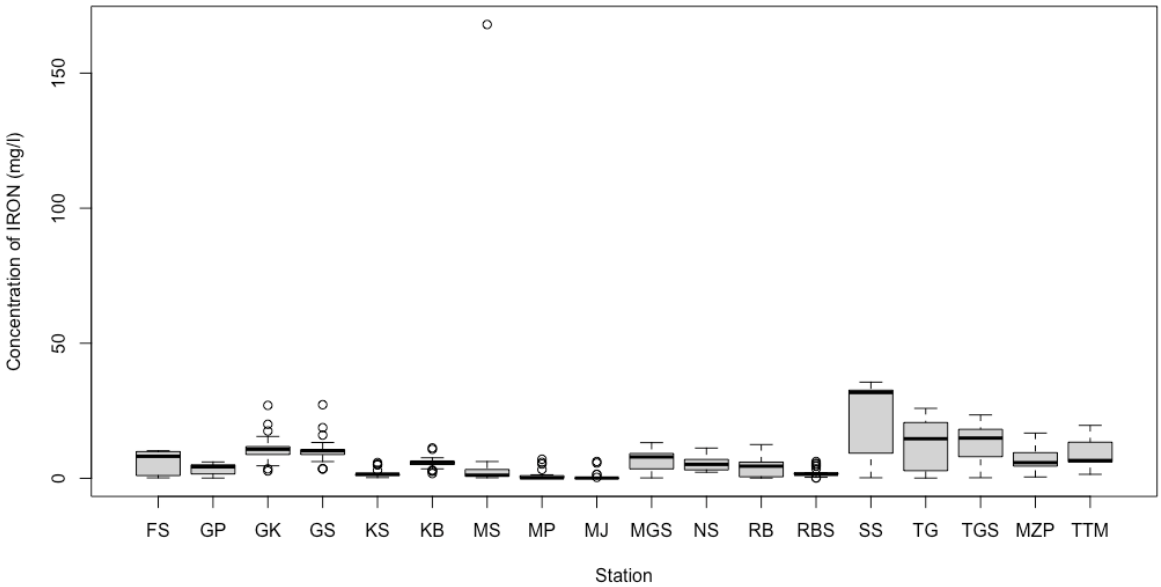

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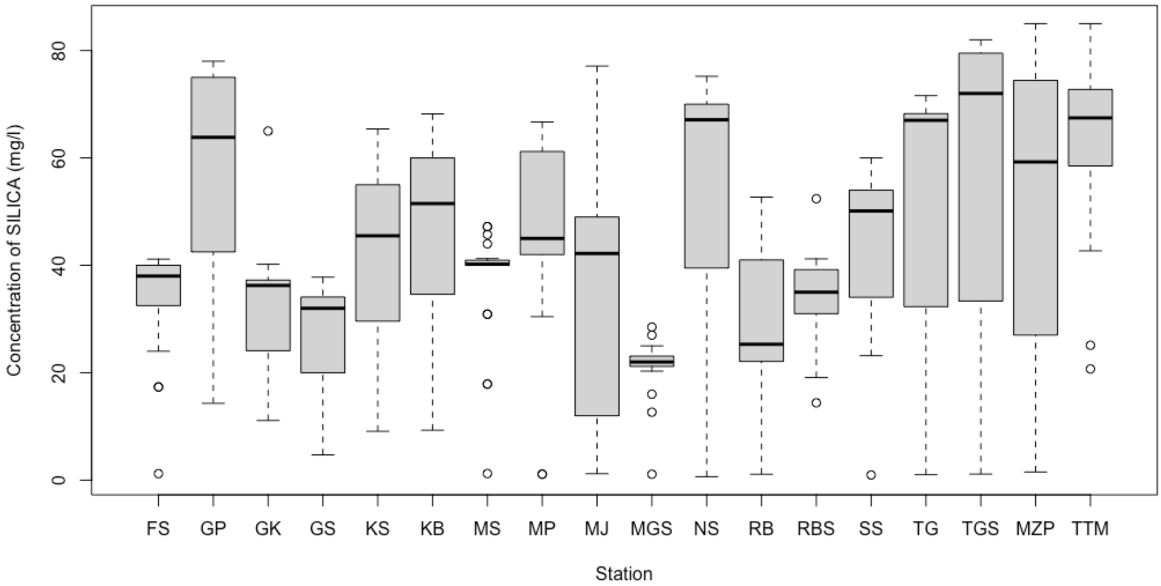

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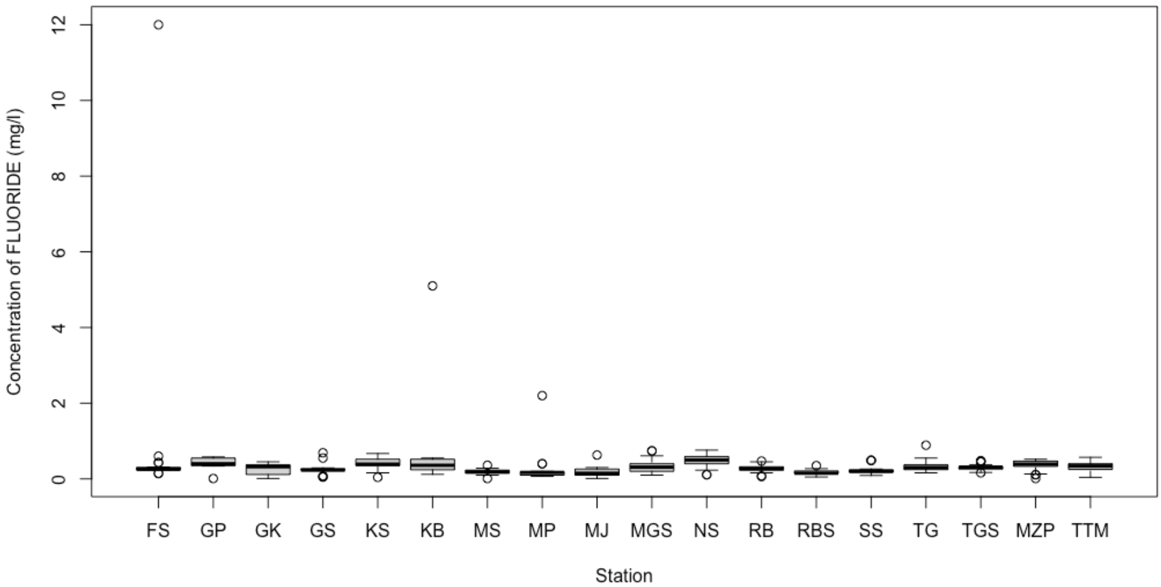
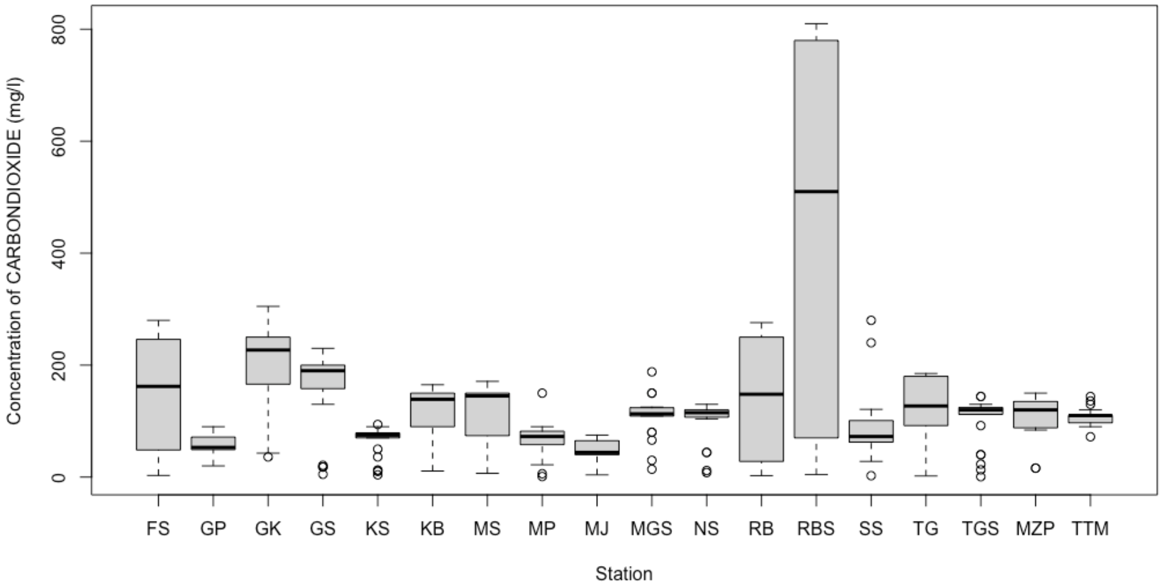
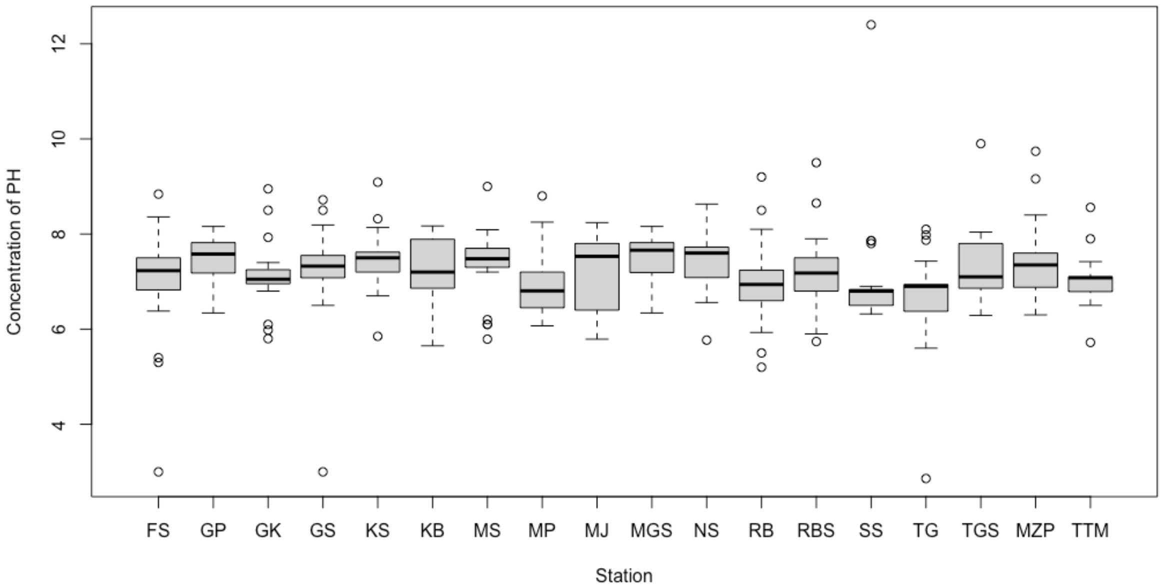


CARBONDIOXIDE

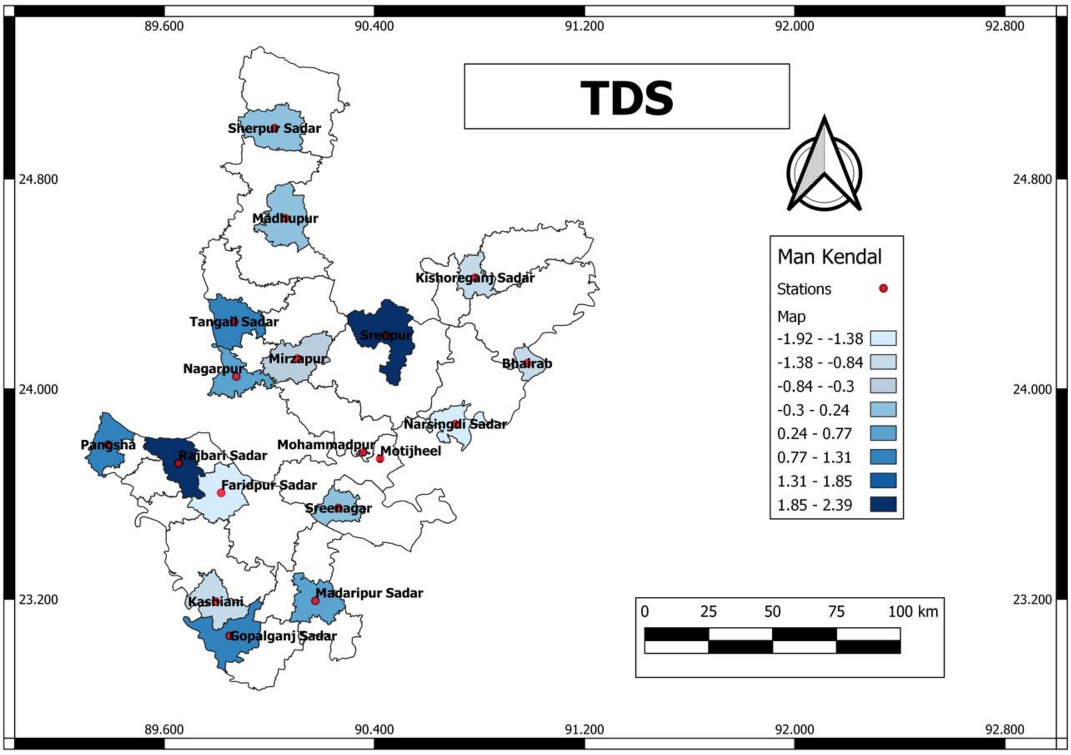


PH

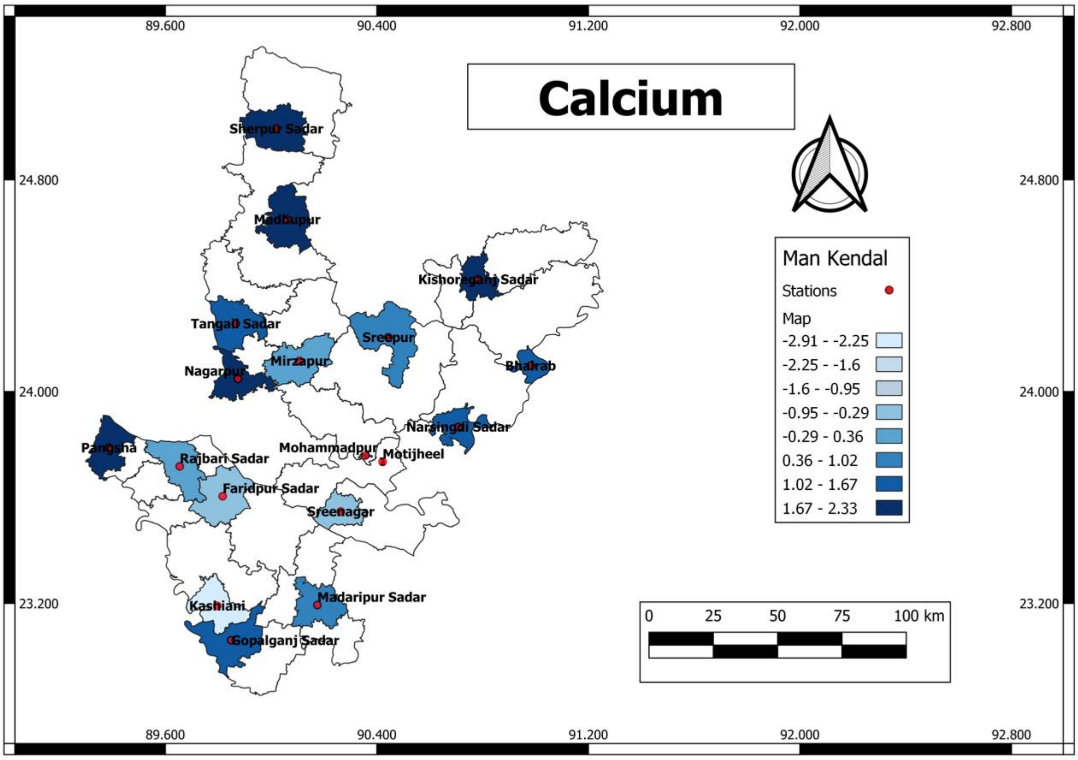


QGIS for Mann-kendall

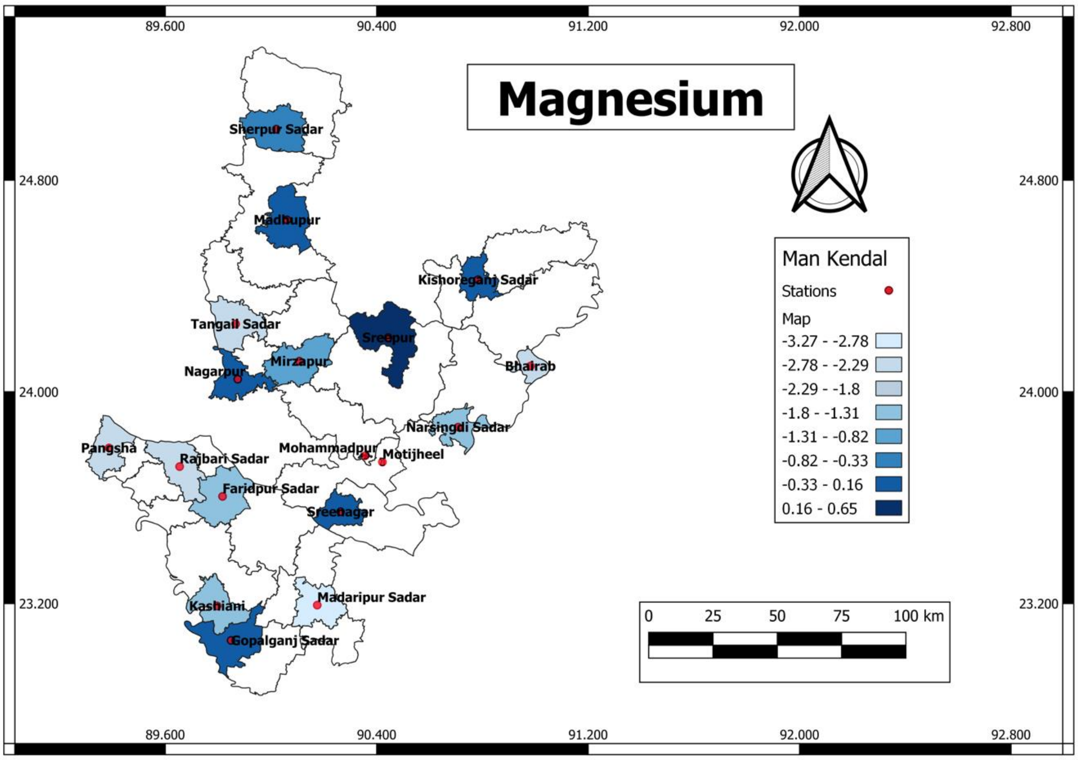
TDS



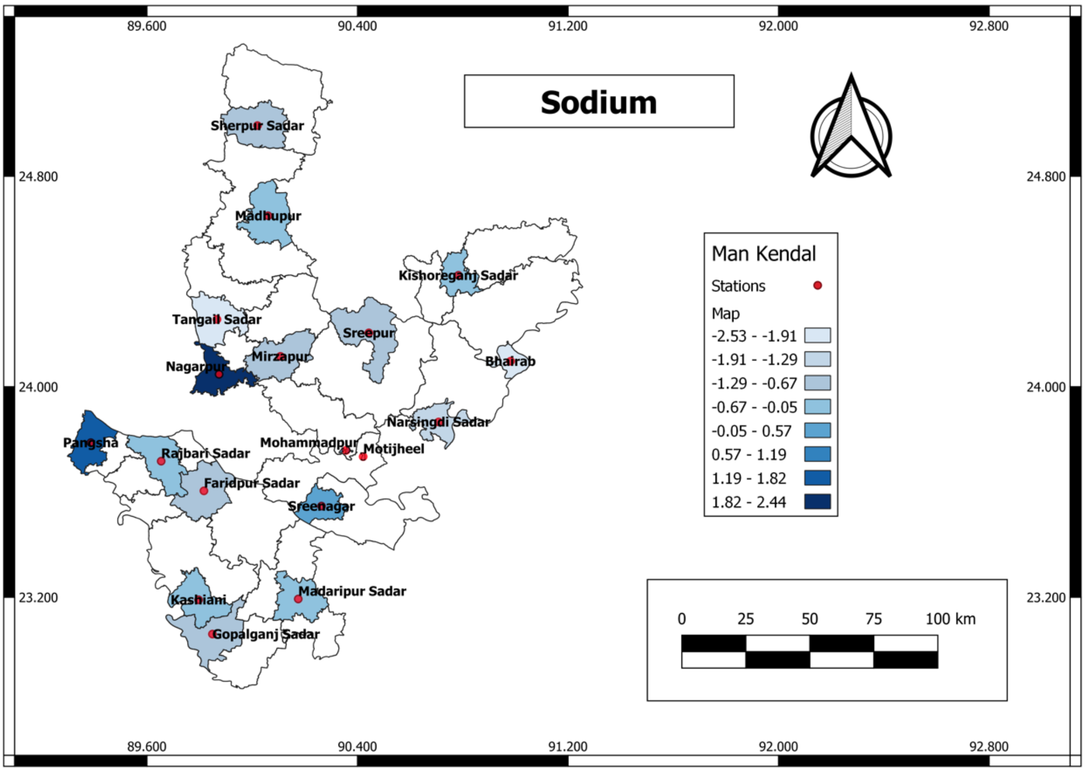
CALCIUM

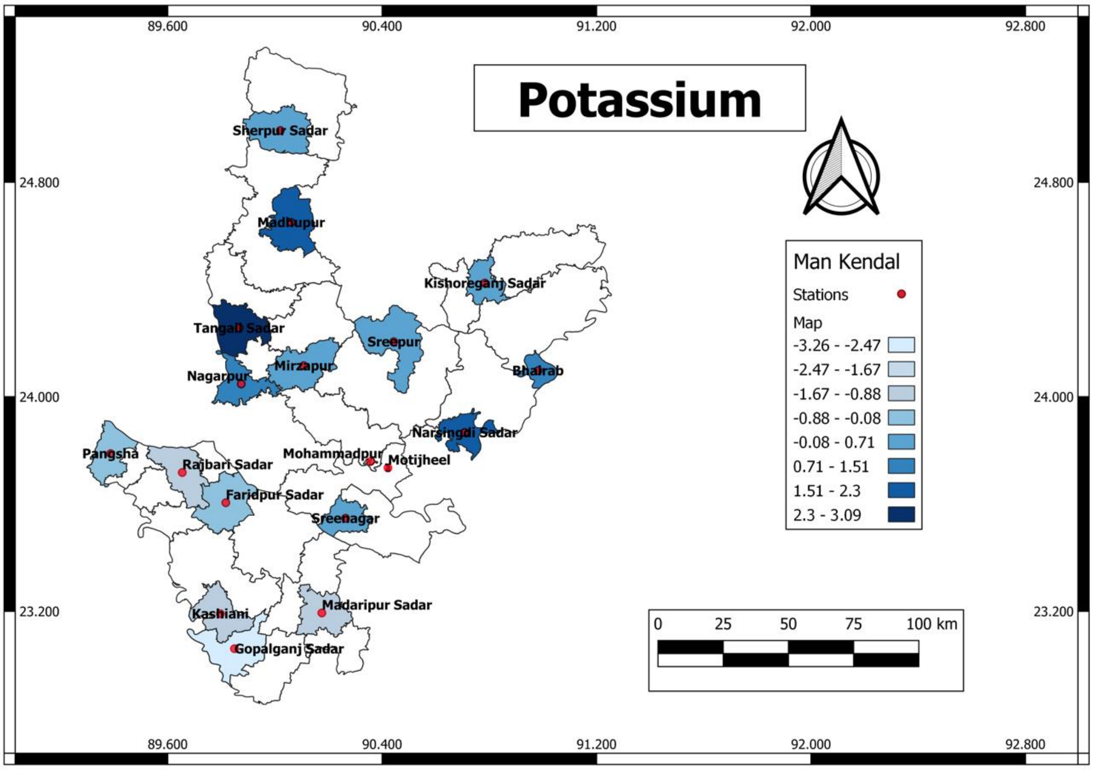


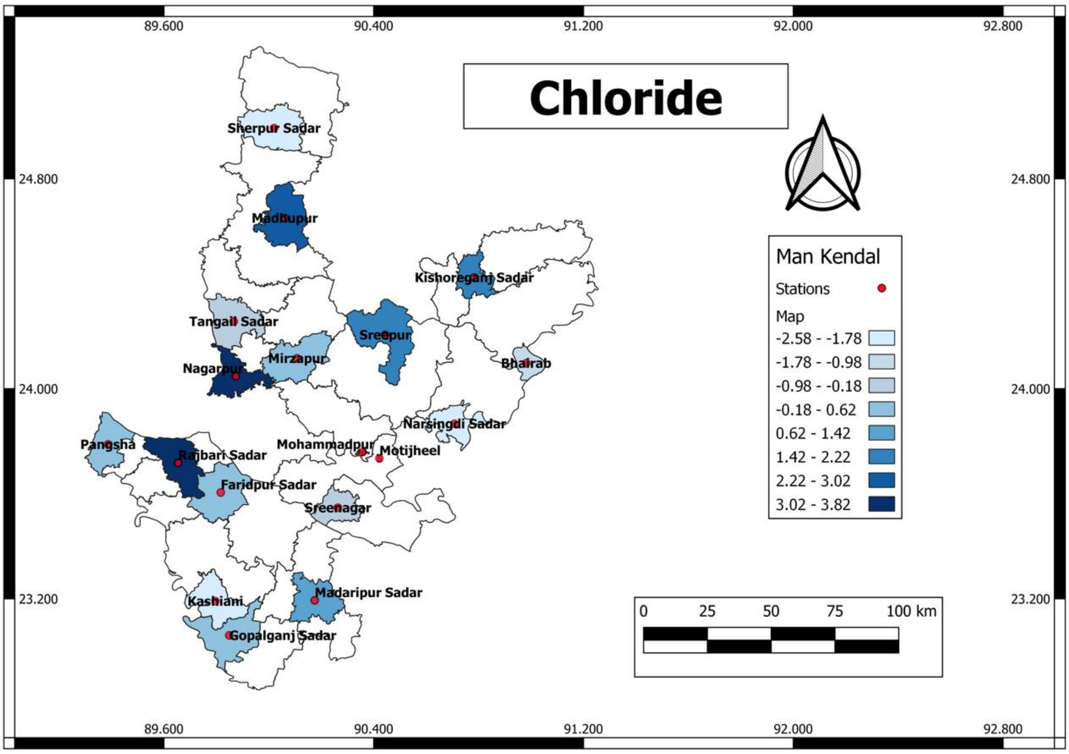
MAGNESIUM



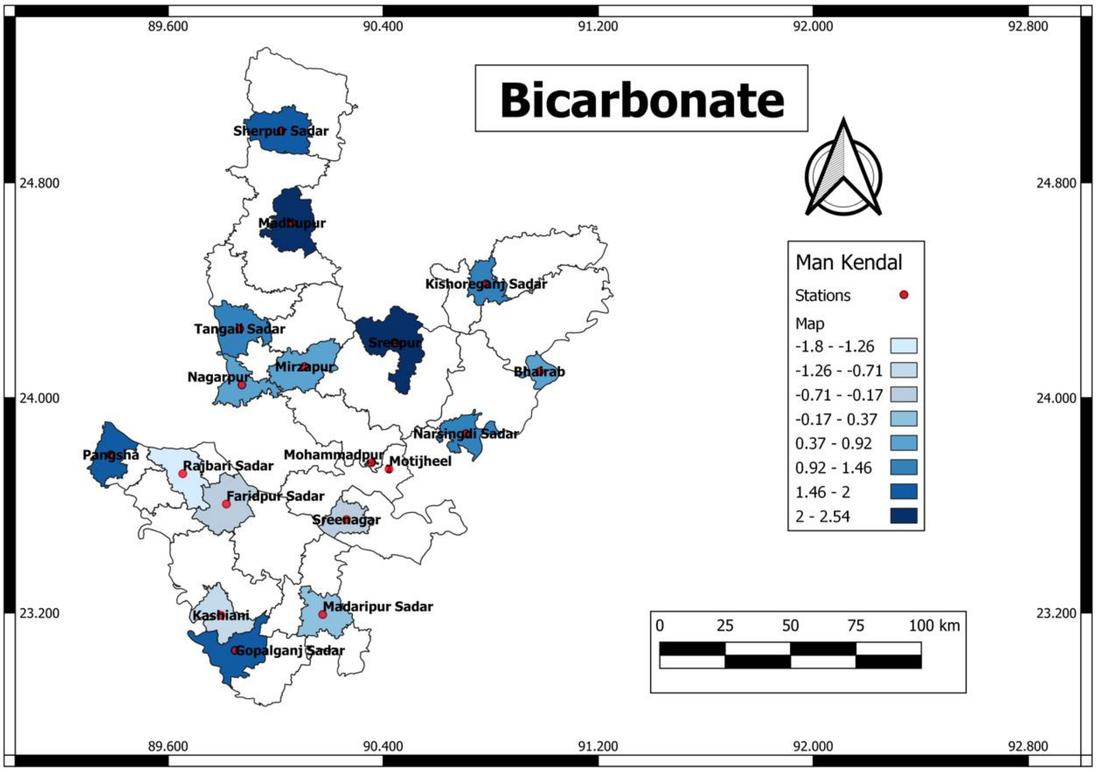
SODIUM



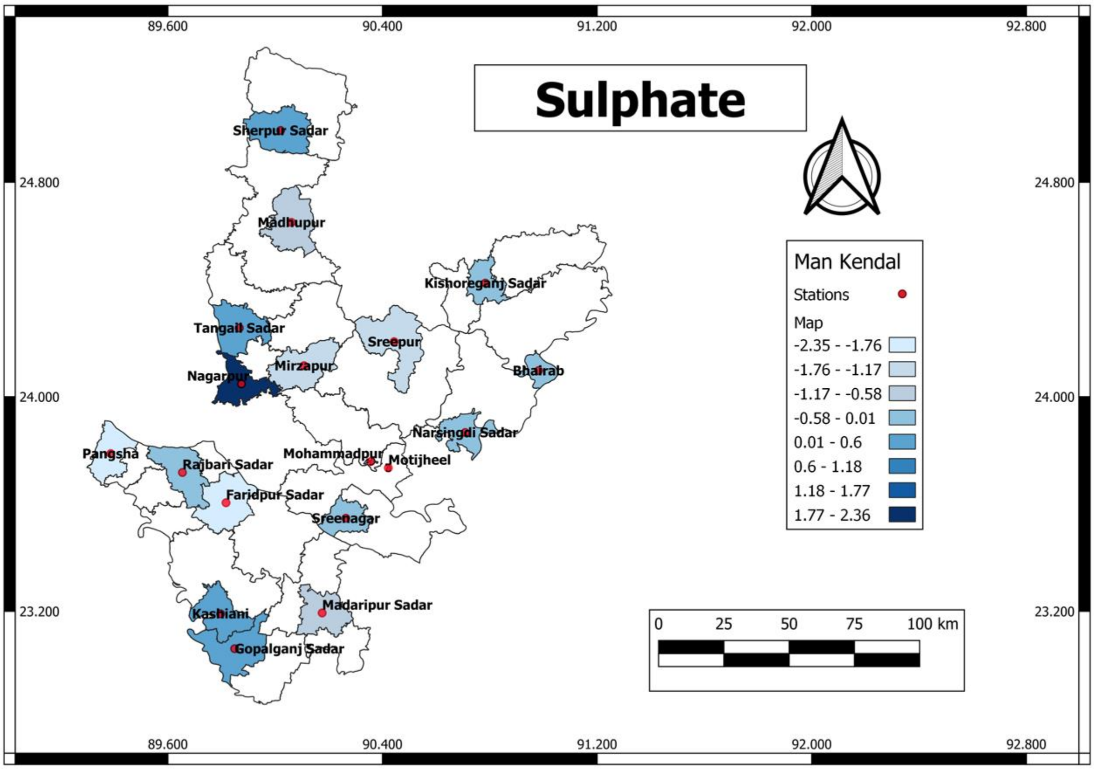
POTASSIUM


CHLORIDE


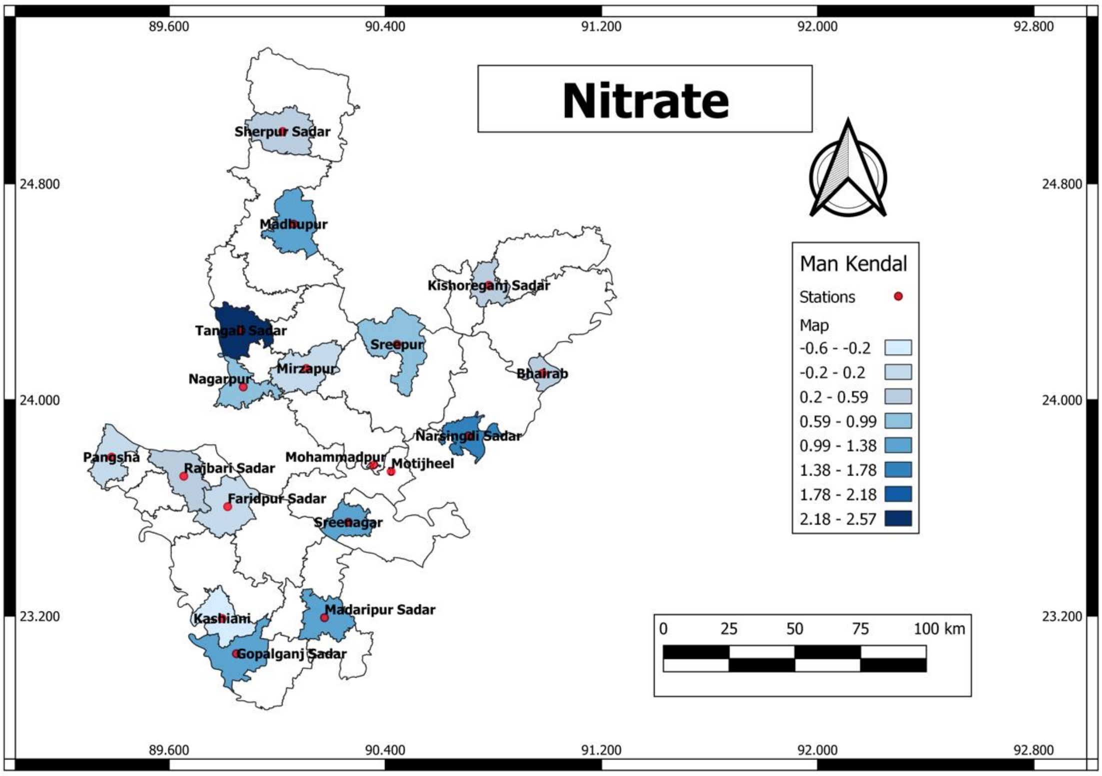
BICARBONATE



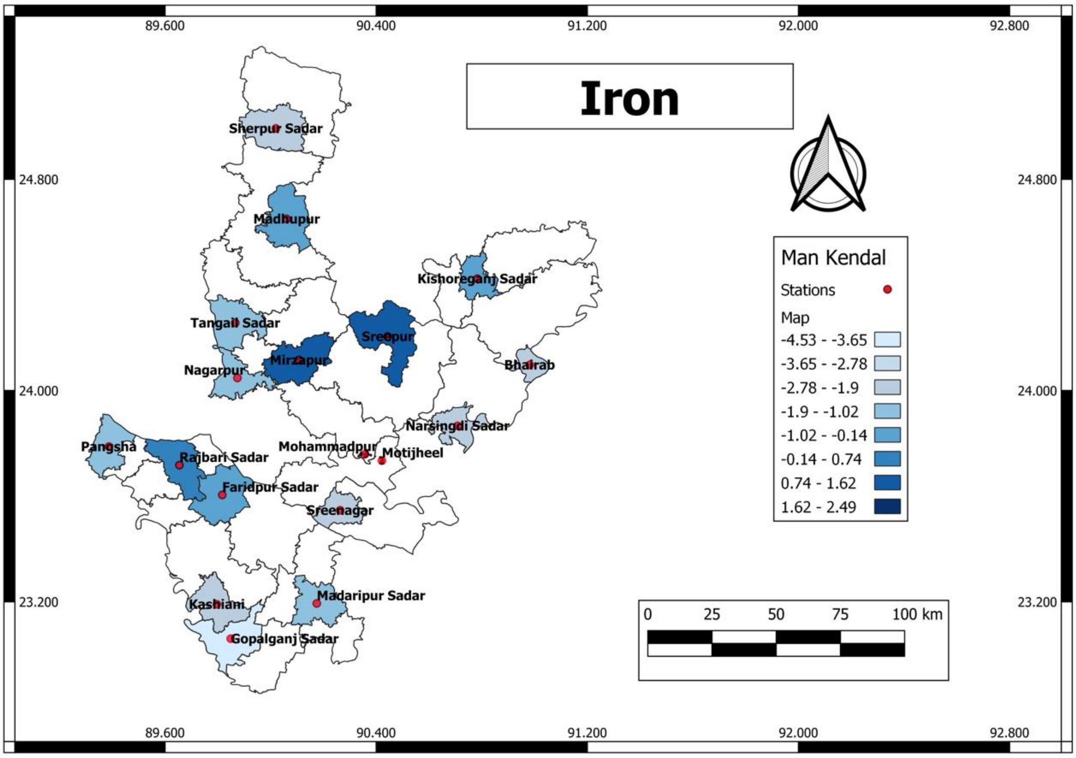
SULPHATE



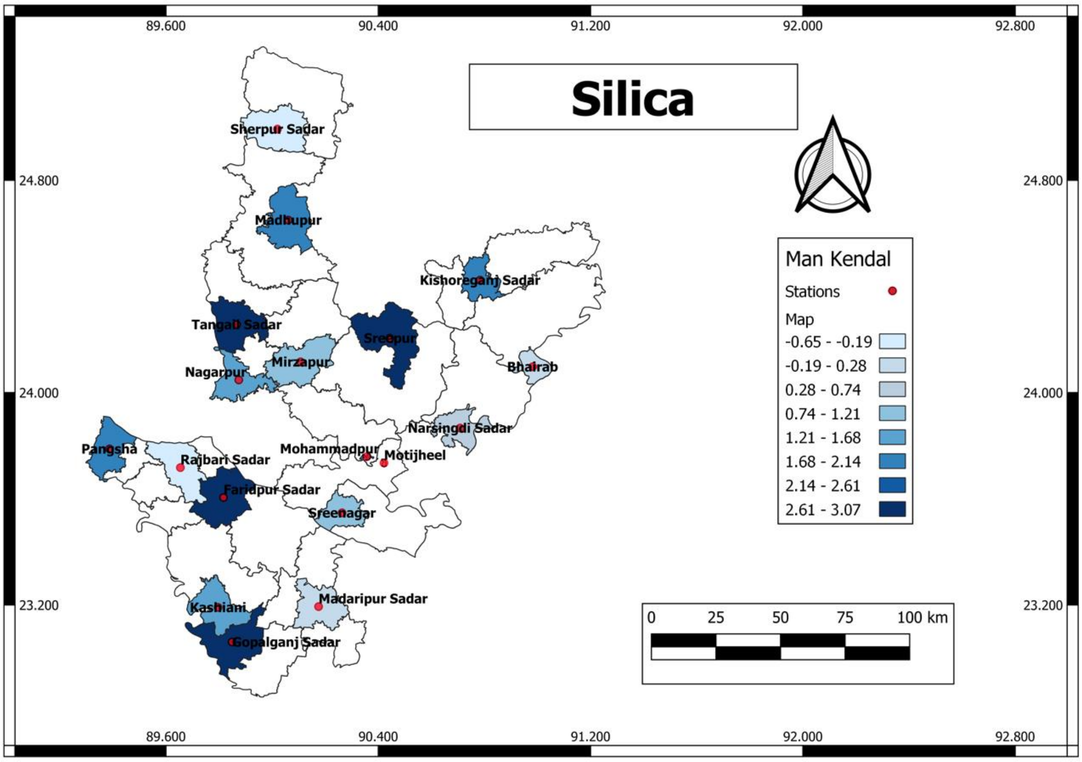
NITRATE



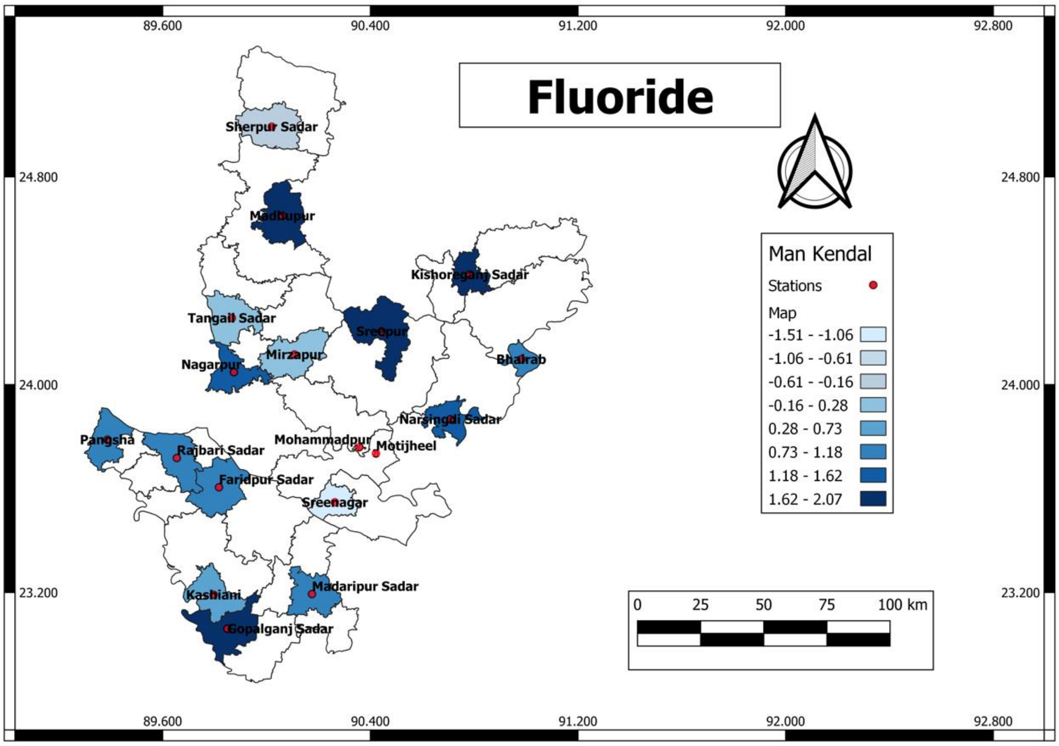
IRON



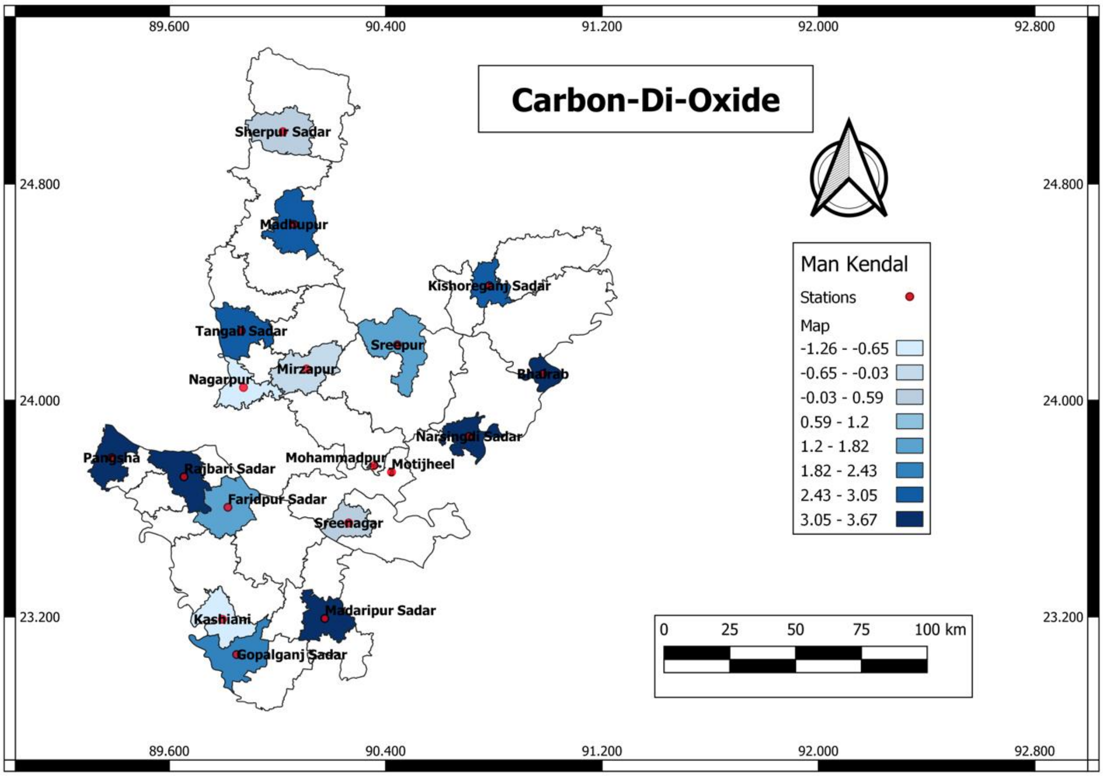
SILICA



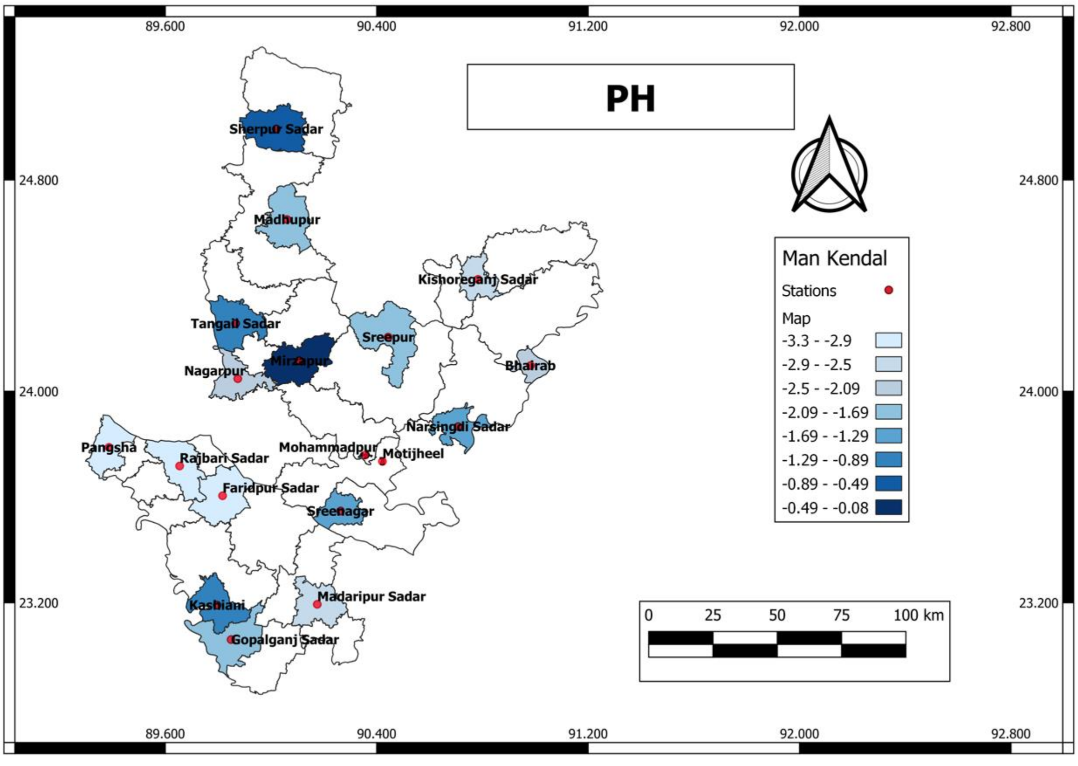
FLUORIDE



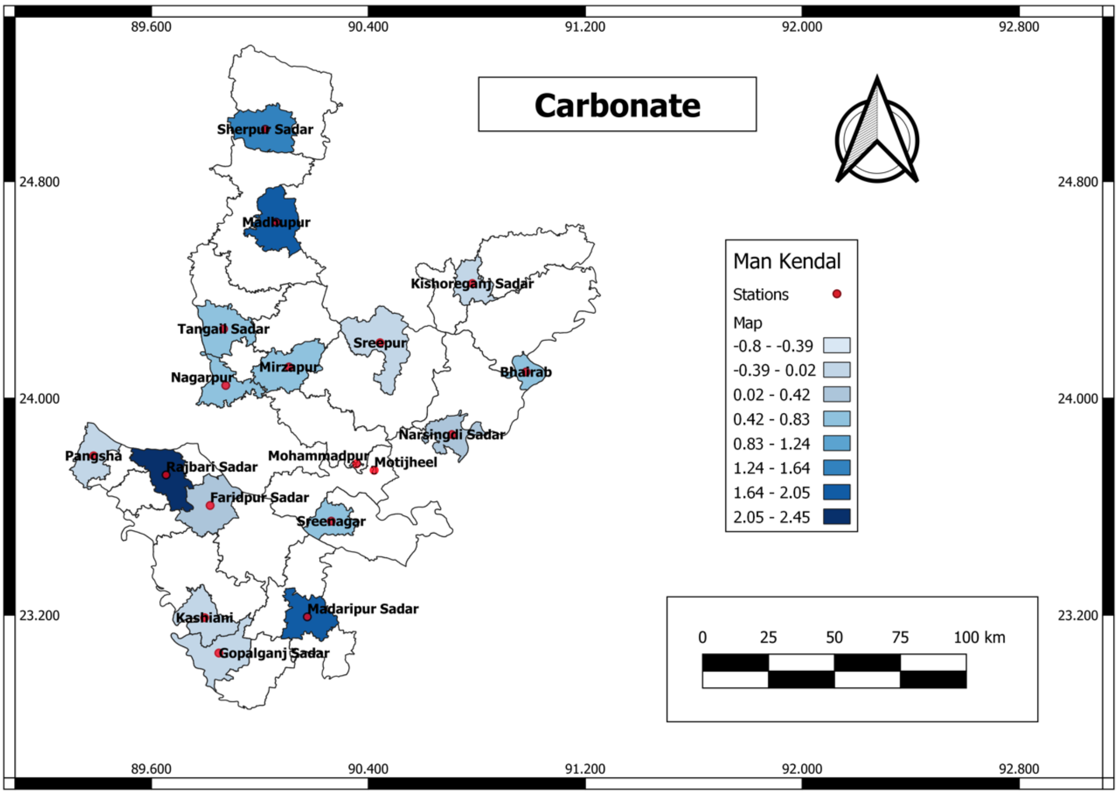
CARBONDIOXIDE



PH

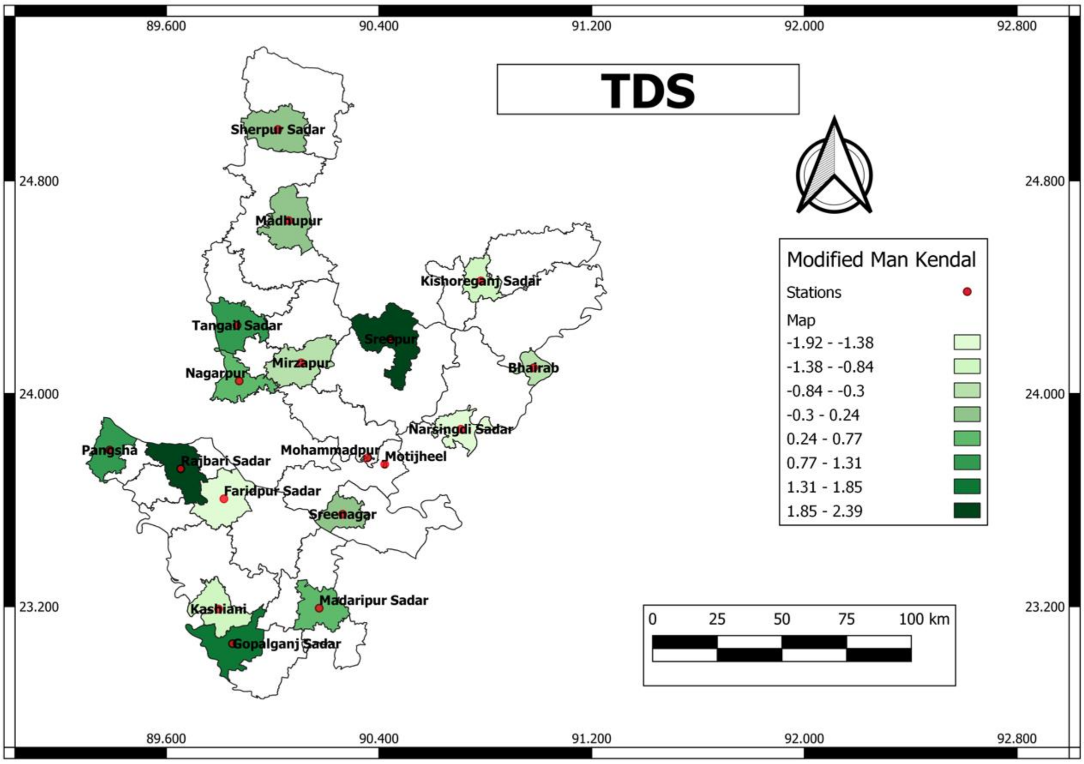


CARBONATE

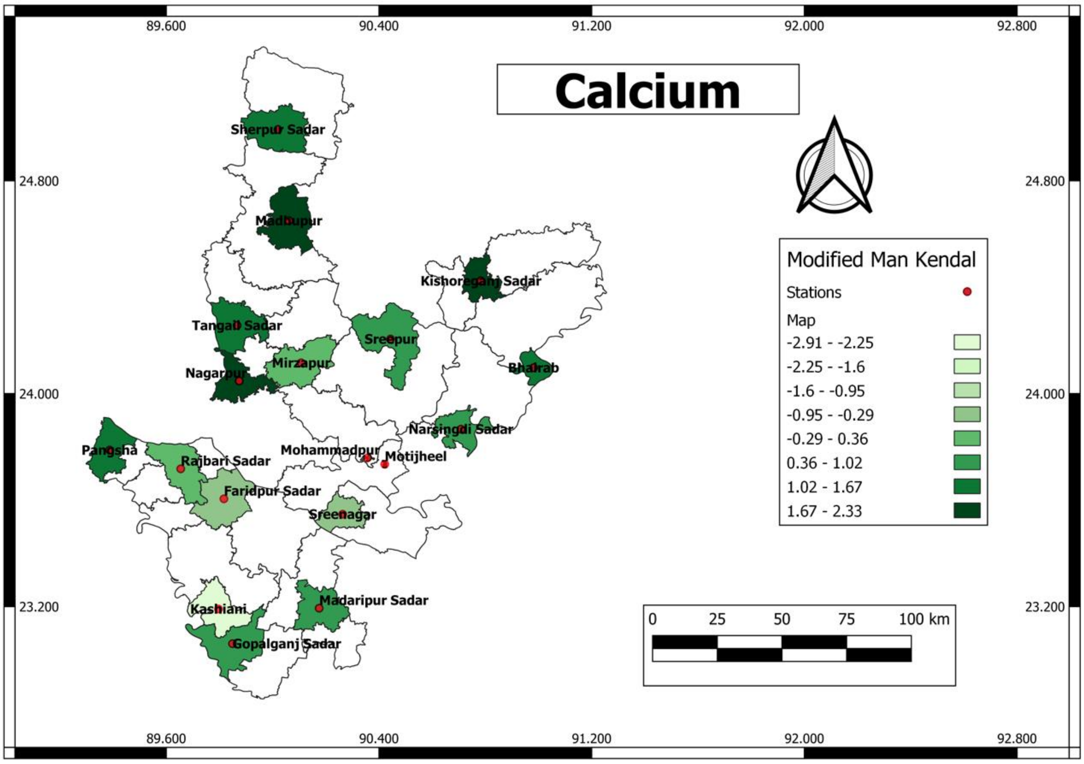

Carbonate
89.600
90.400
91.200
92.000
92.800
24.800
24.000
23.200
Sherpur Sadar
Madhupur
Kishoreganj Sadar
Tangail Sadar
Sreepur
Mirzapur
Nagarpur
Bhairab
Narsingdi Sadar
Pangsha
Rajbari Sadar
Mohammadpur
Motijheel
Faridpur Sadar
Sreenagar
Kashiani
Madaripur Sadar
Gopalganj Sadar
Man Kendal
Stations
Map
-0.8 - -0.39
-0.39 - 0.02
0.02 - 0.42
0.42 - 0.83
0.83 - 1.24
1.24 - 1.64
1.64 - 2.05
2.05 - 2.45
0
25
50
75
100 km

QGIS for Modified Mann-kendall

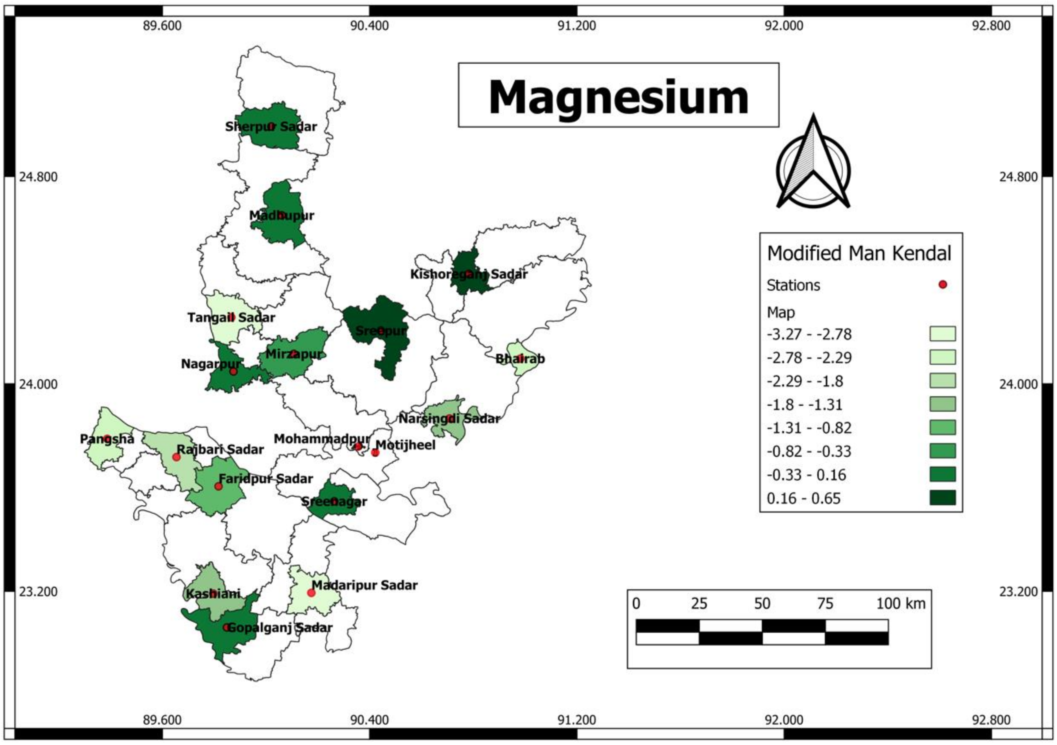
TDS



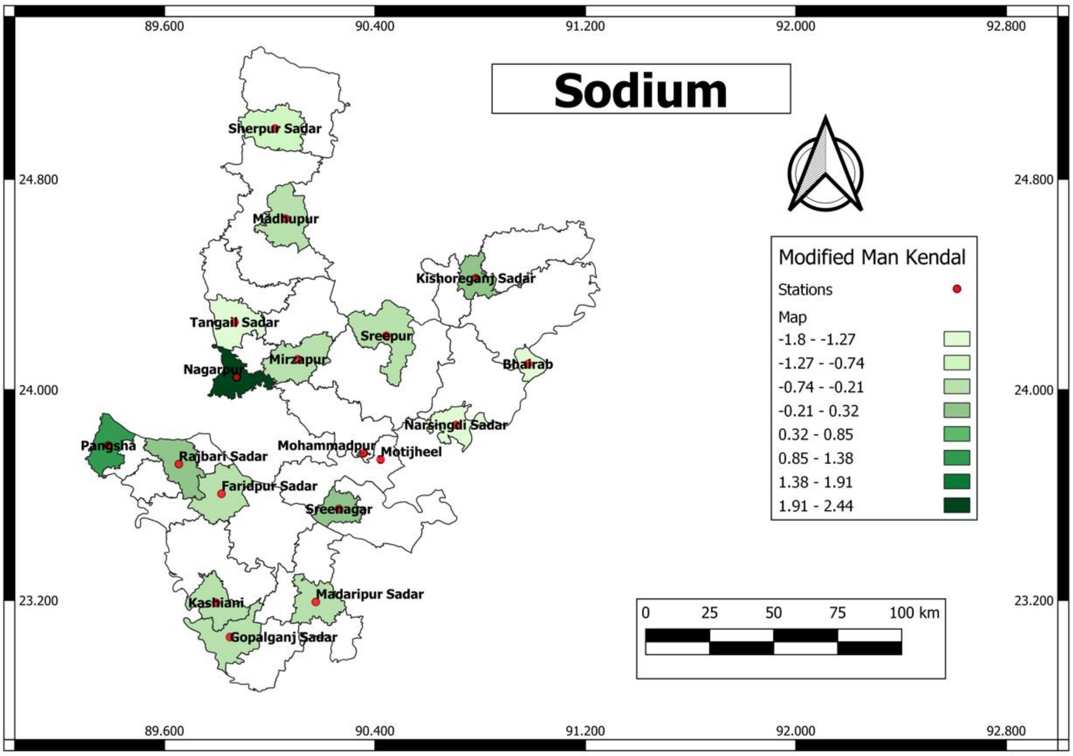
CALCIUM



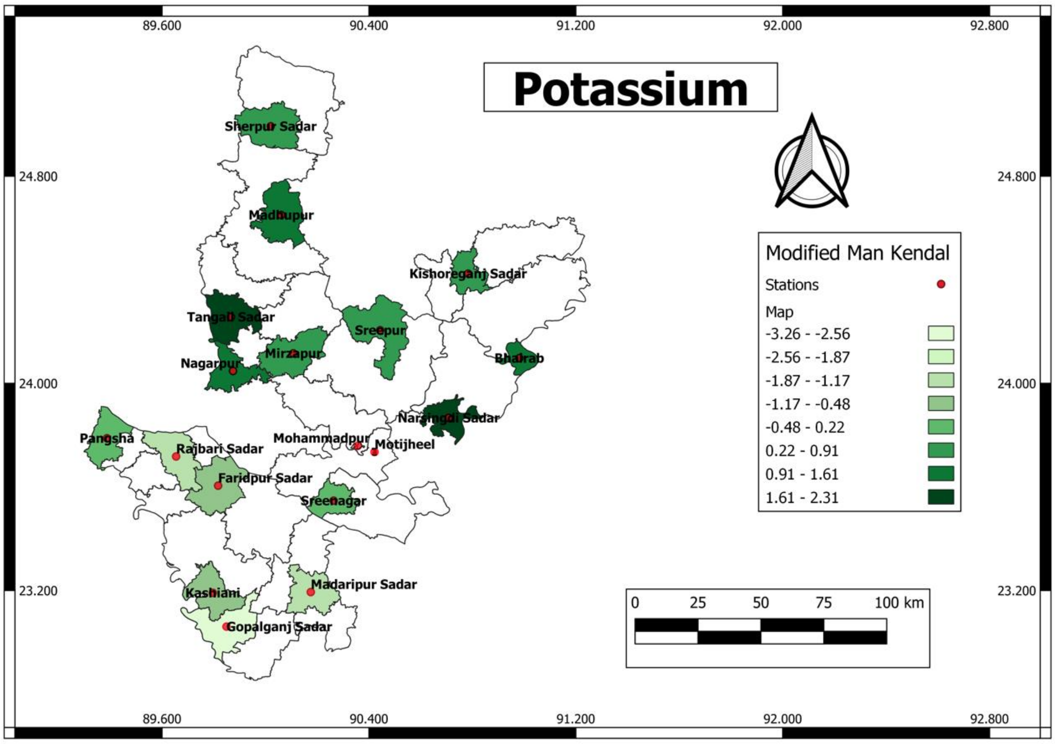
MAGNESIUM



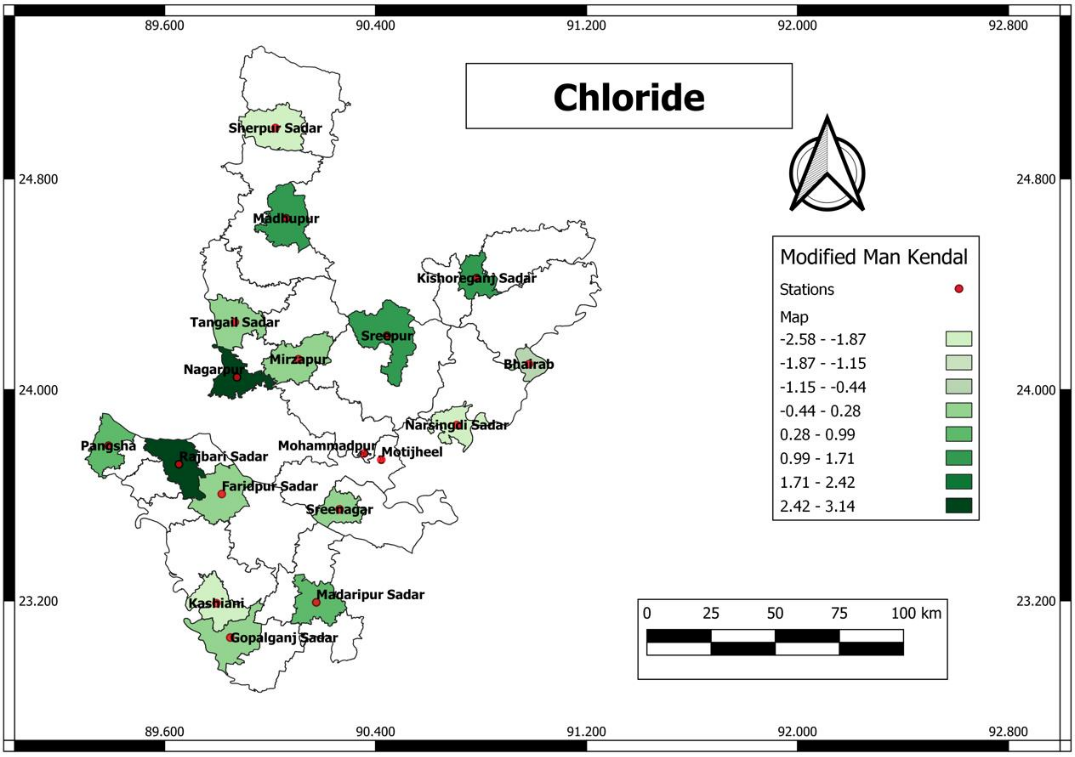
SODIUM



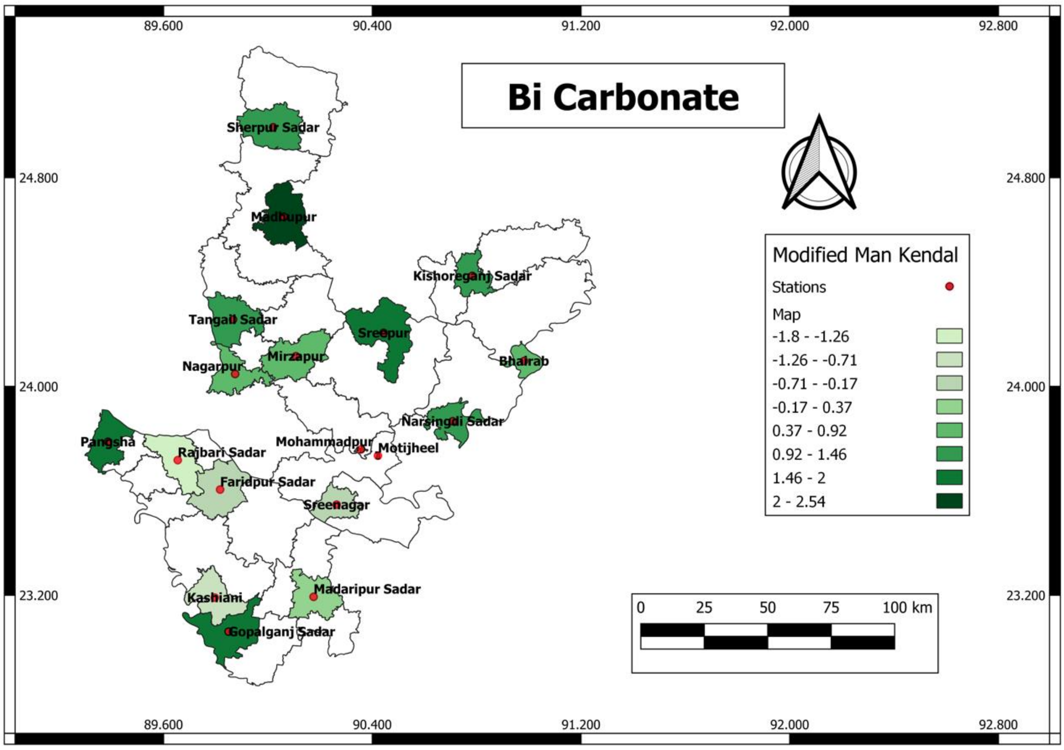
POTASSIUM



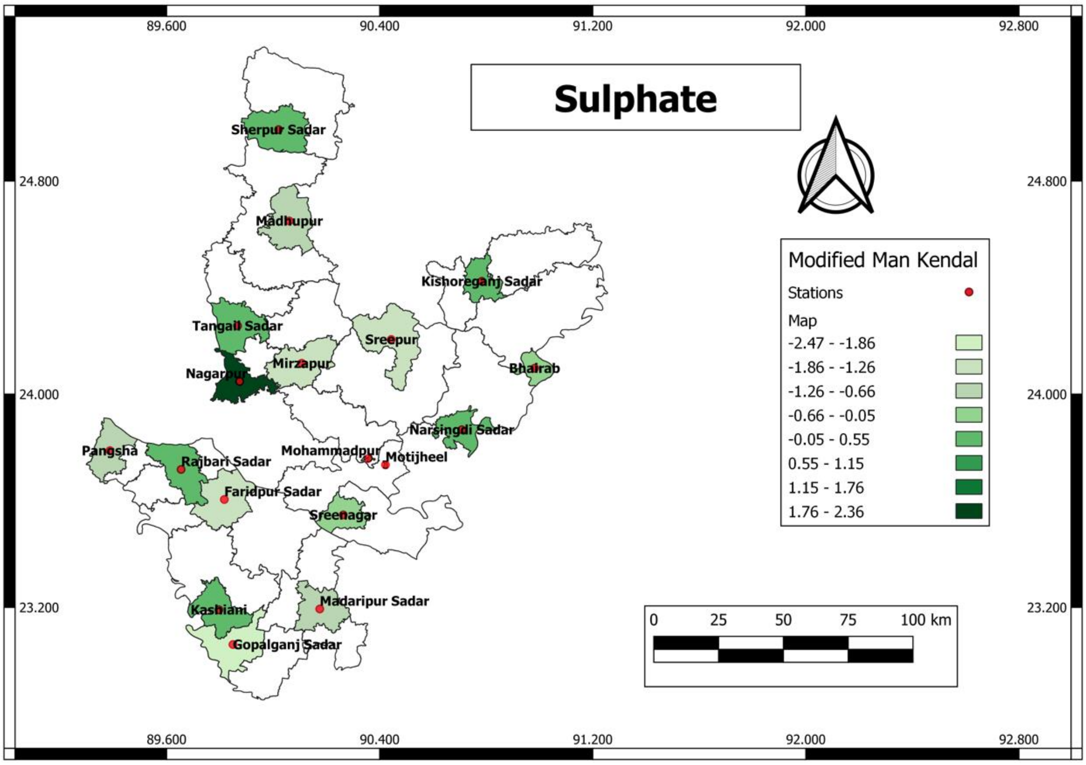
CHLORIDE



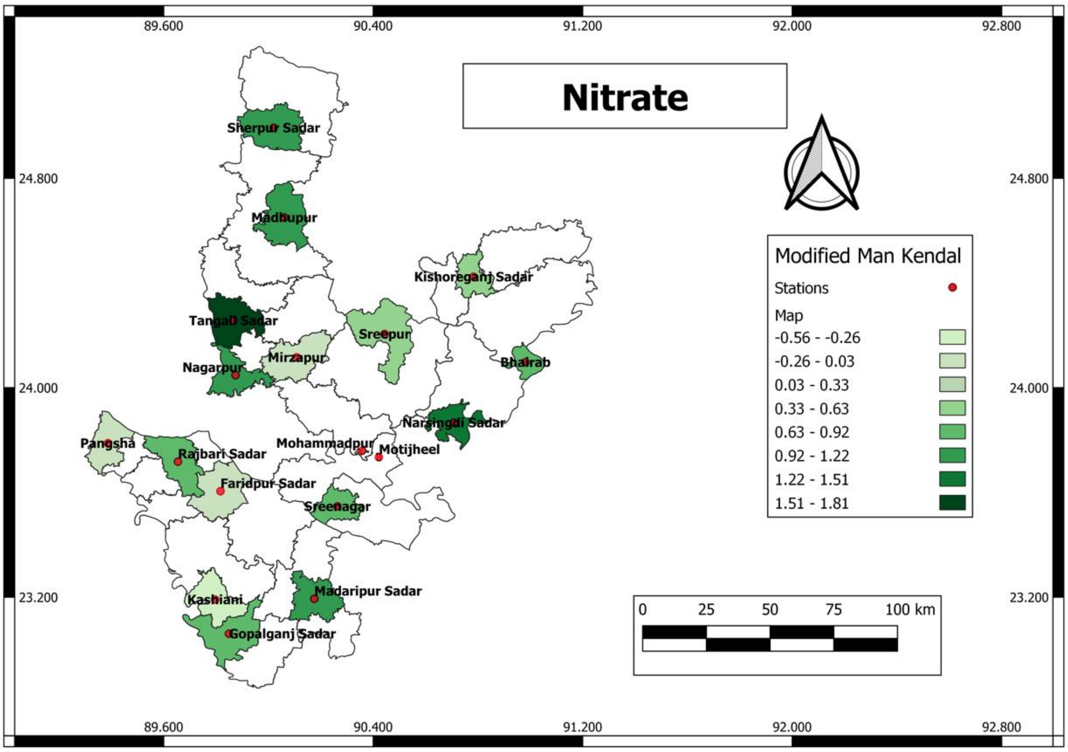
BICARBONATE



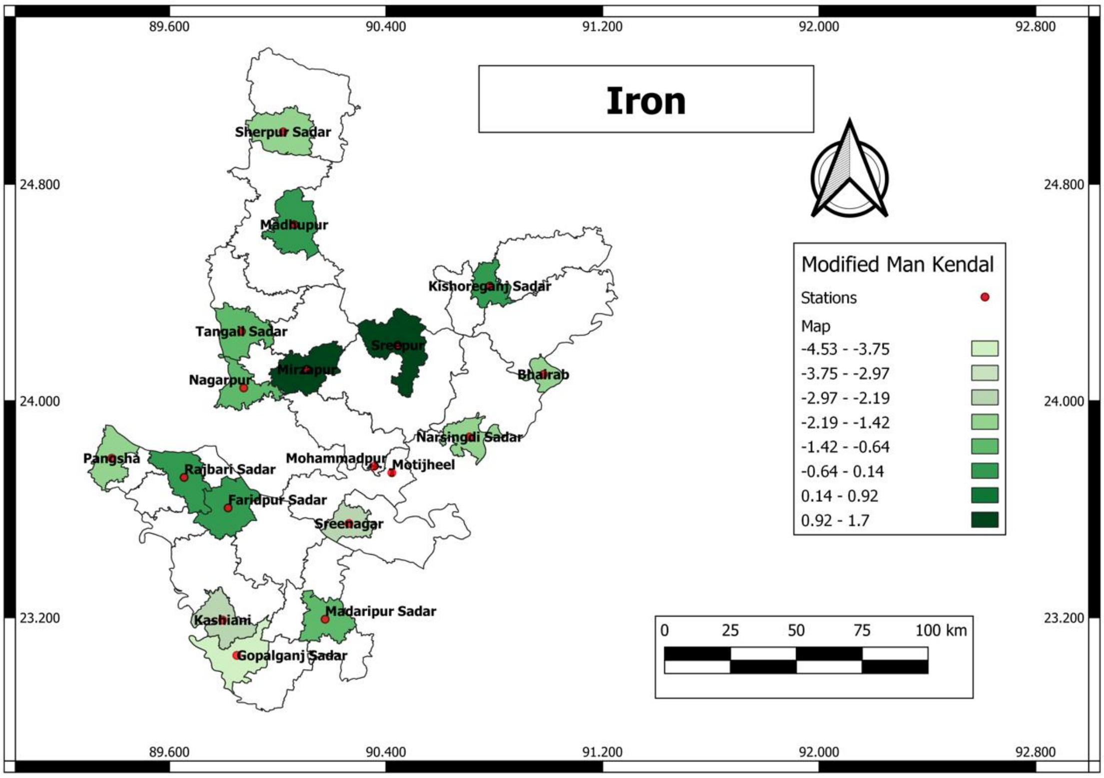
SULPHATE



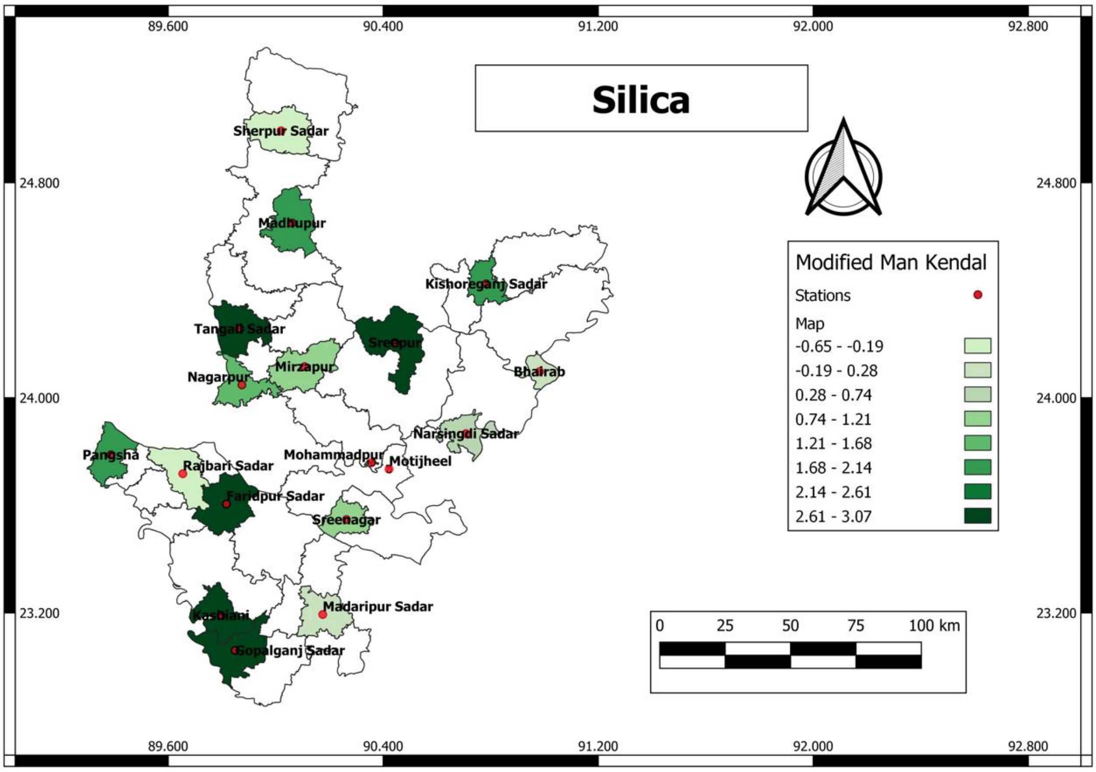
NITRATE



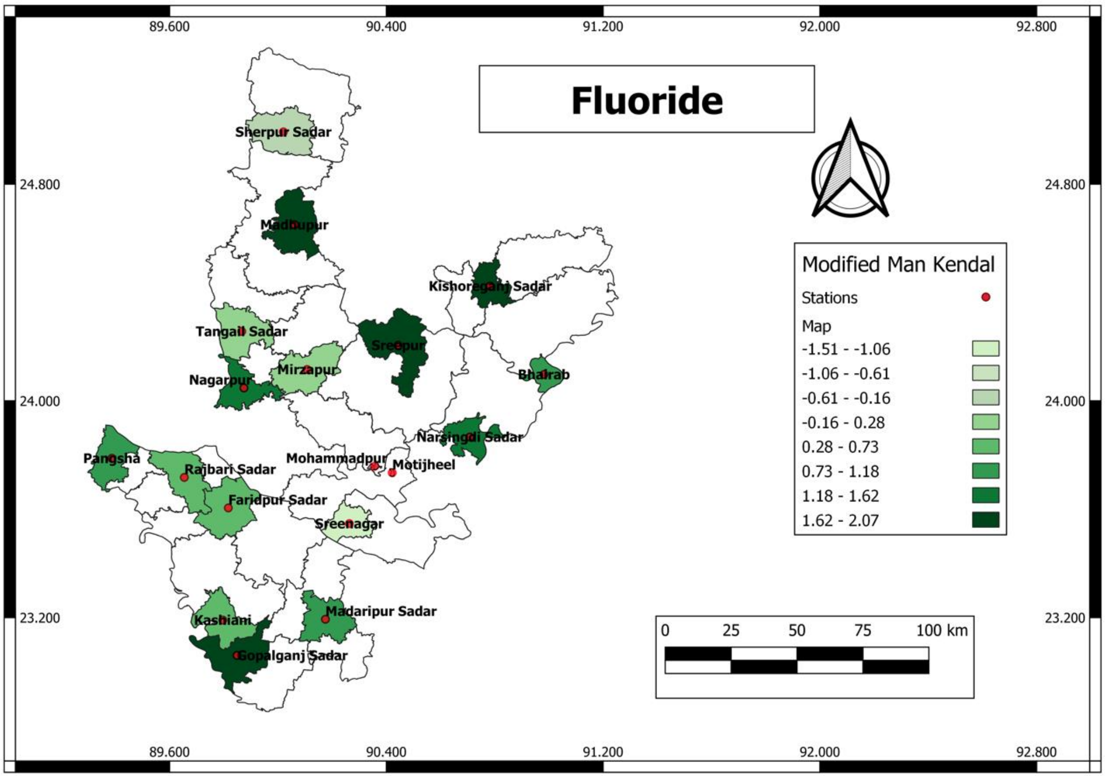
IRON



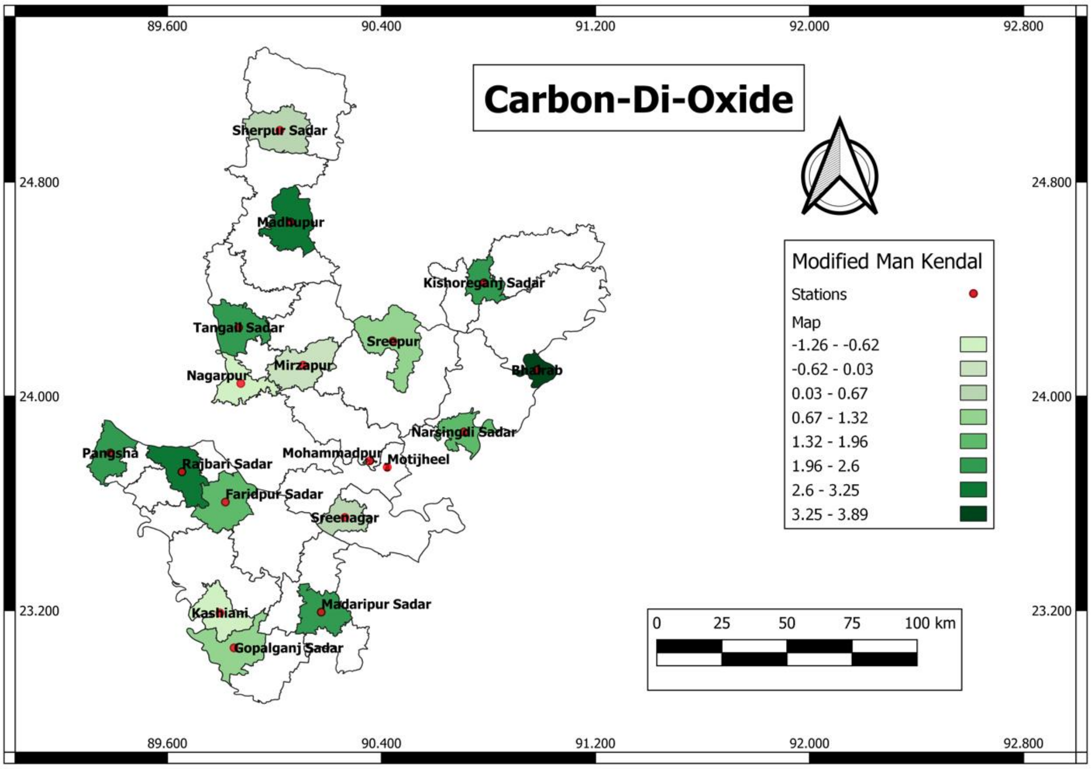
SILICA



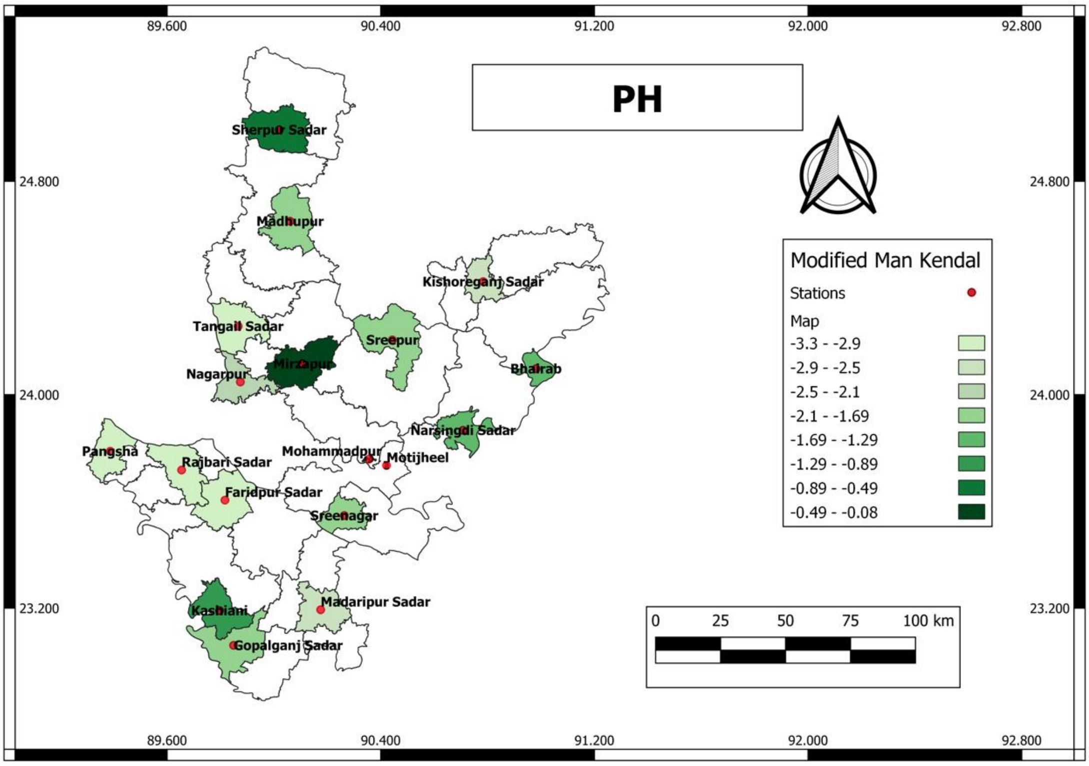
FLUORIDE



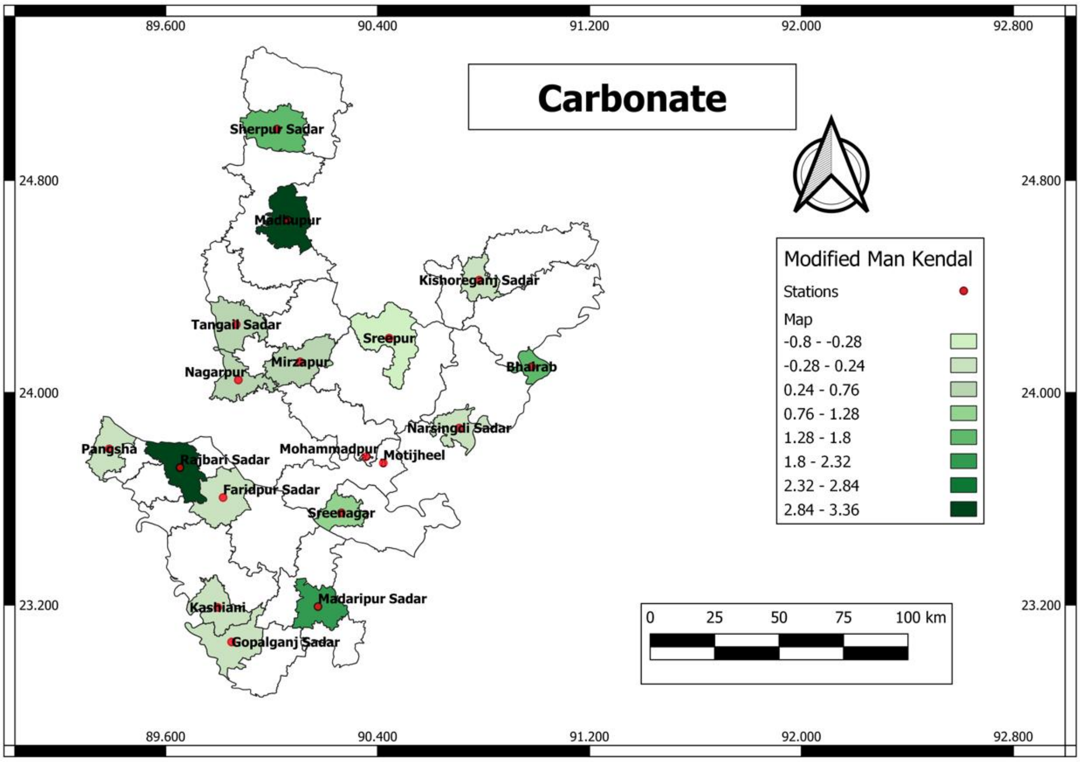
CARBONDIOXIDE



PH

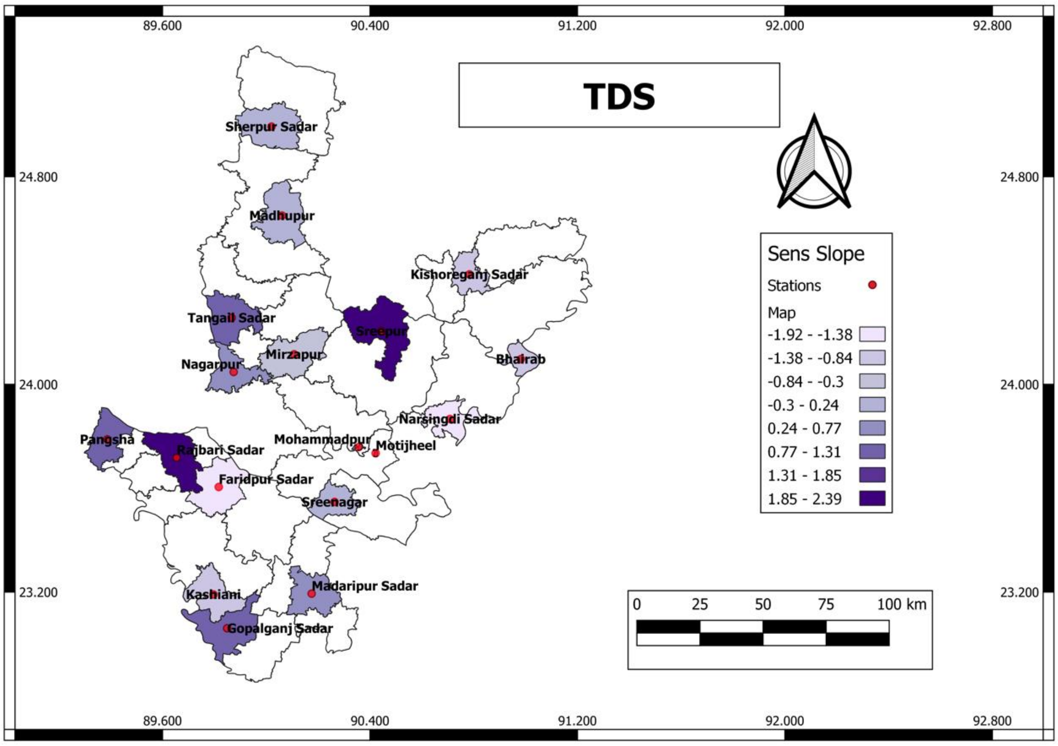


CARBONATE

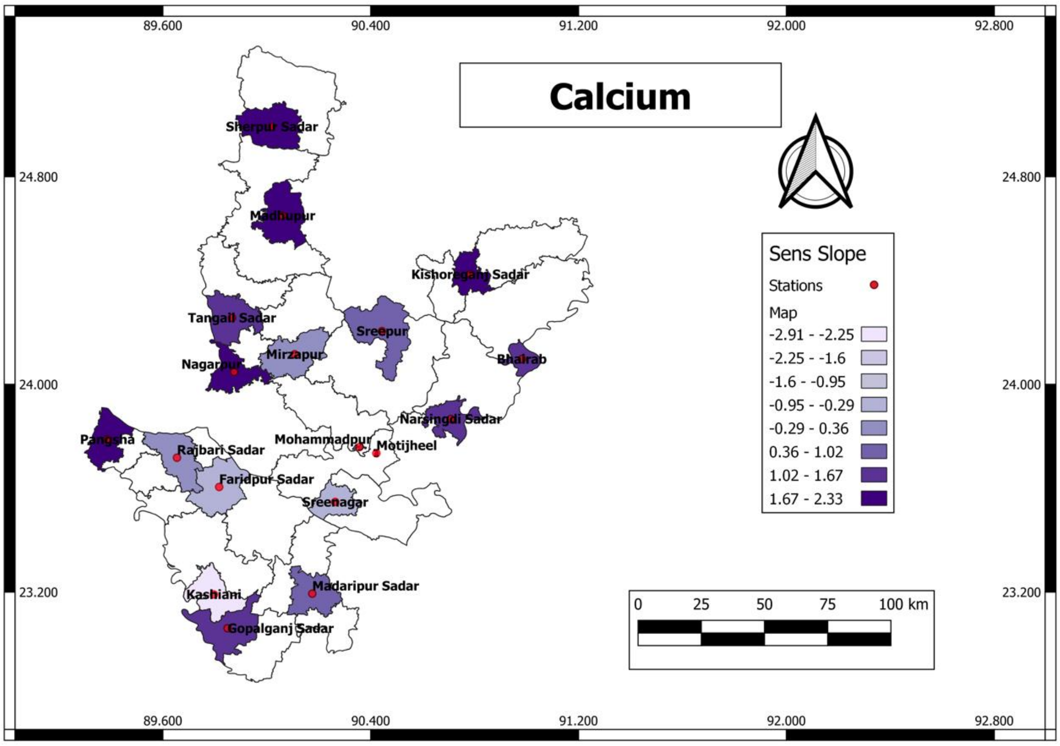

Carbonate
89.600
90.400
91.200
92.000
92.800
24.800
24.000
23.200
Modified Man Kendal
Stations
Map
-0.8 - -0.28
-0.28 - 0.24
0.24 - 0.76
0.76 - 1.28
1.28 - 1.8
1.8 - 2.32
2.32 - 2.84
2.84 - 3.36
0
25
50
75
100 km
Sherpur Sadar
Madhupur
Kishoreganj Sadar
Tangail Sadar
Sreepur
Mirzapur
Nagarpur
Bhairab
Narsingdi Sadar
Pangsha
Rajbari Sadar
Mohammadpur
Motijheel
Faridpur Sadar
Sreenagar
Kashiani
Madaripur Sadar
Gopalganj Sadar

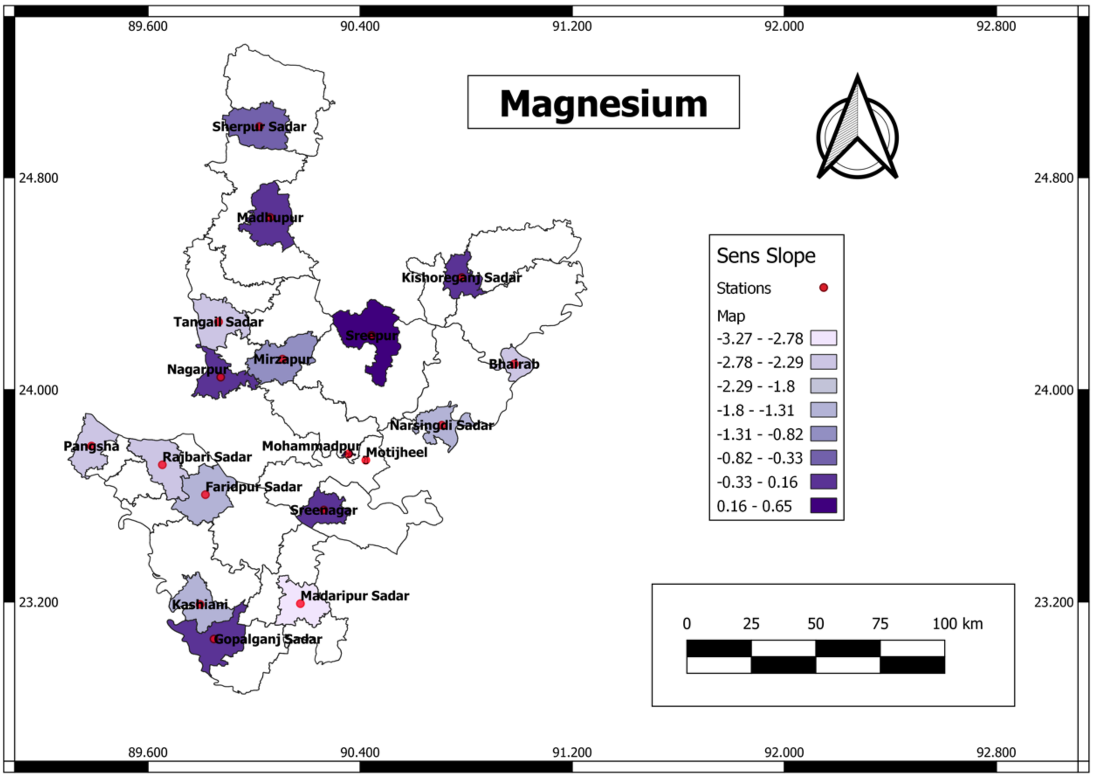
QGIS for Sen's Slope

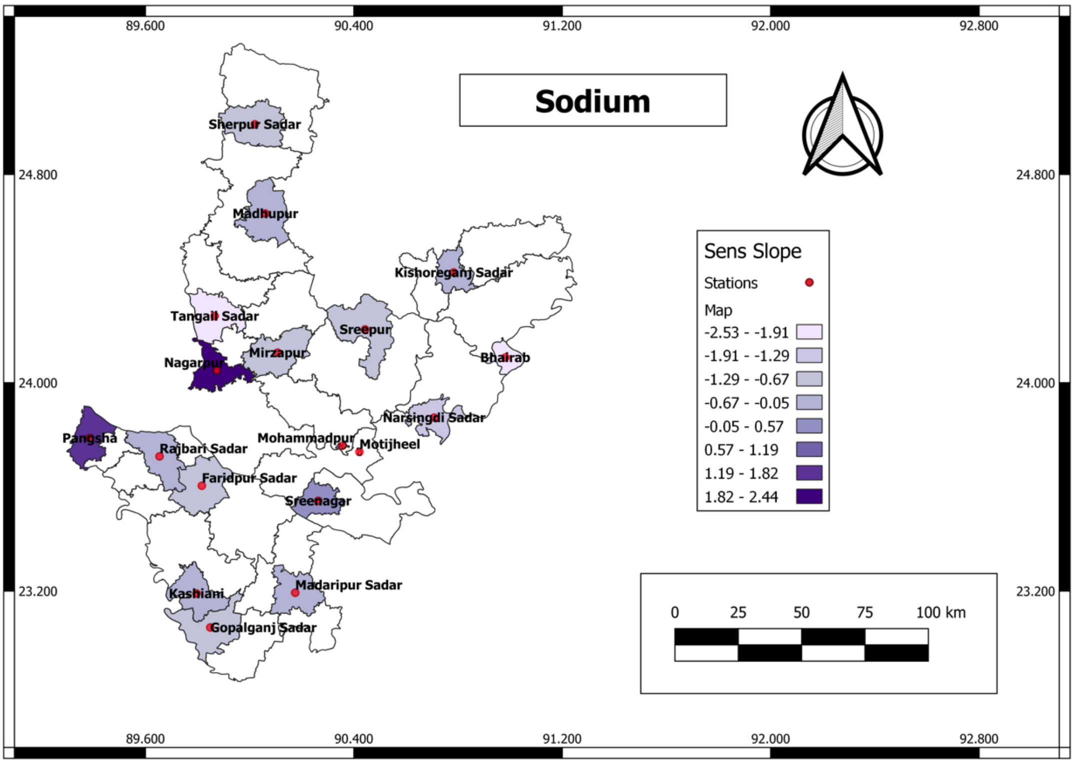
TDS



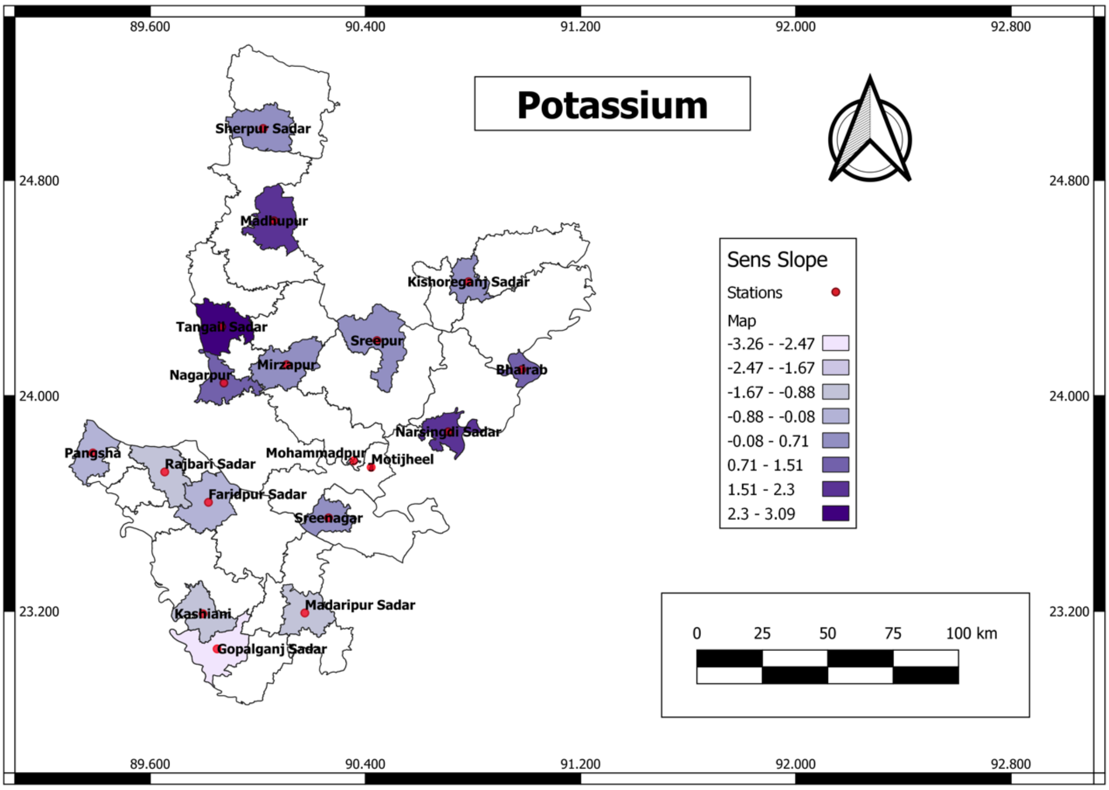
CALCIUM



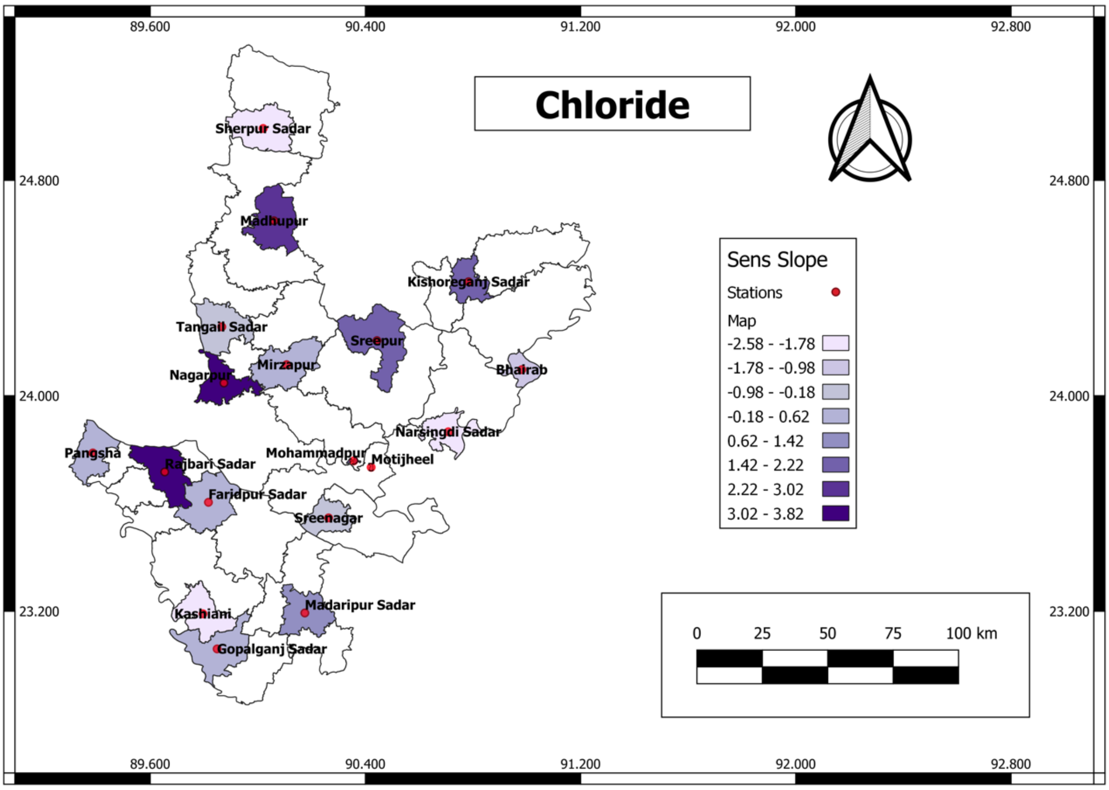
MAGNESIUM


SODIUM


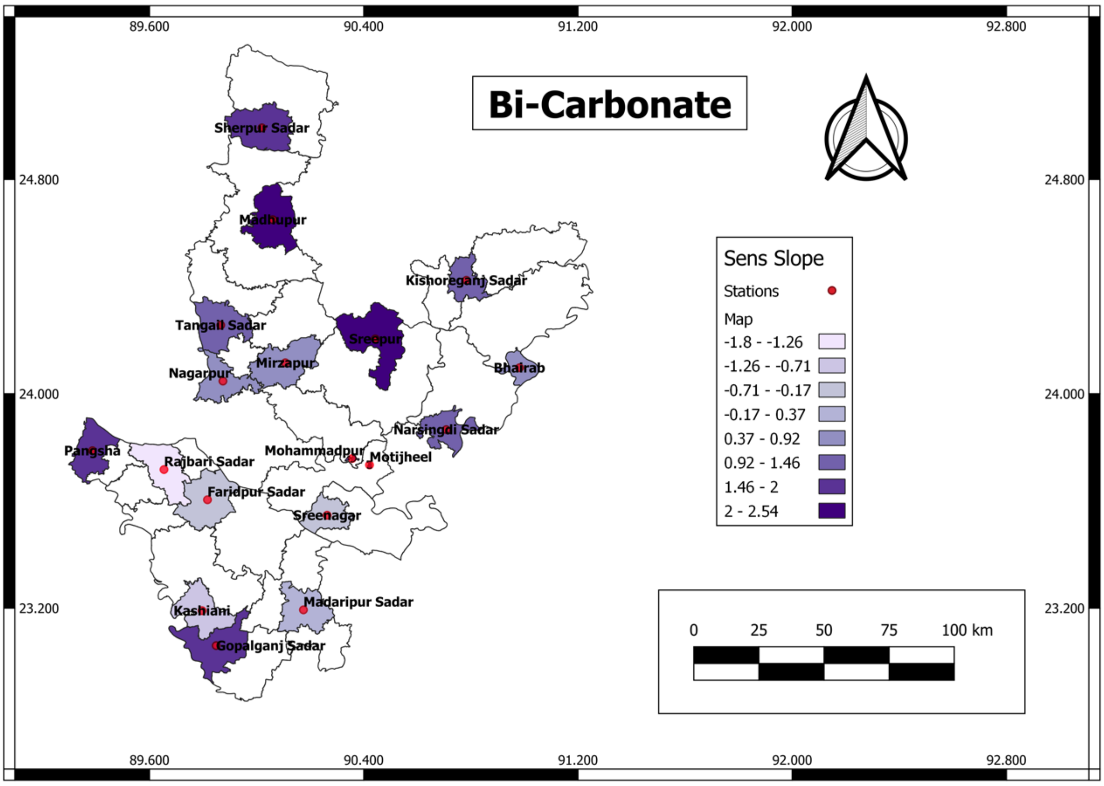
POTASSIUM



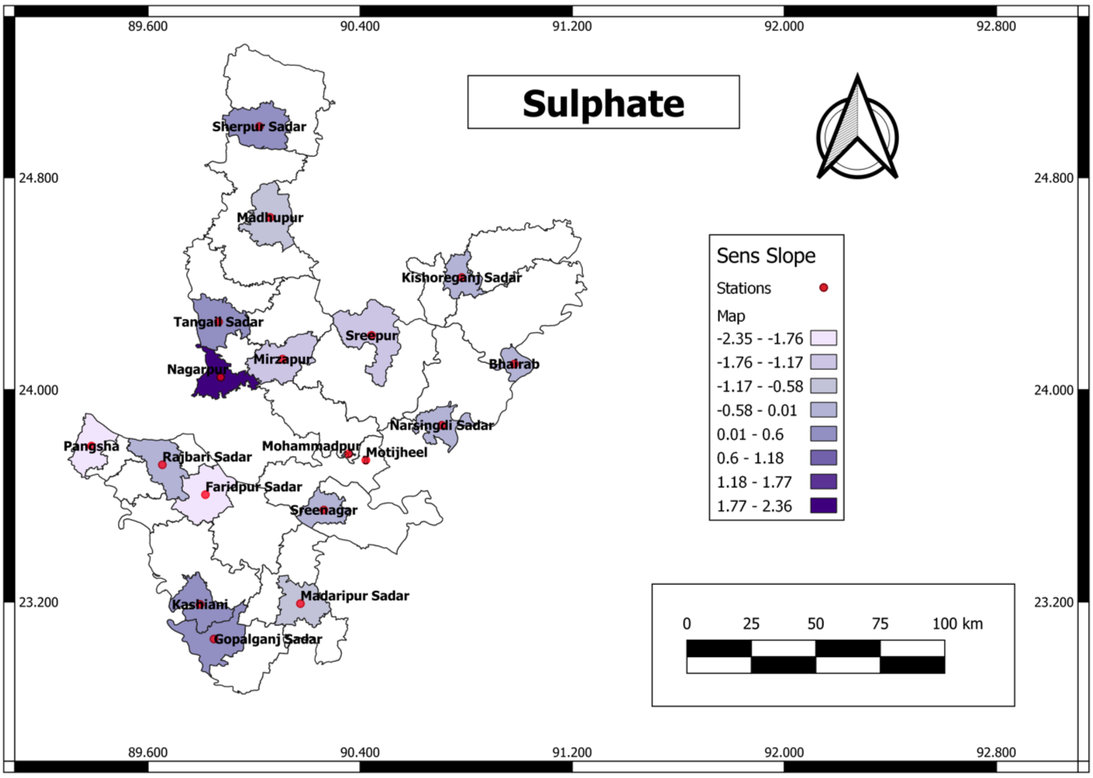
CHLORIDE



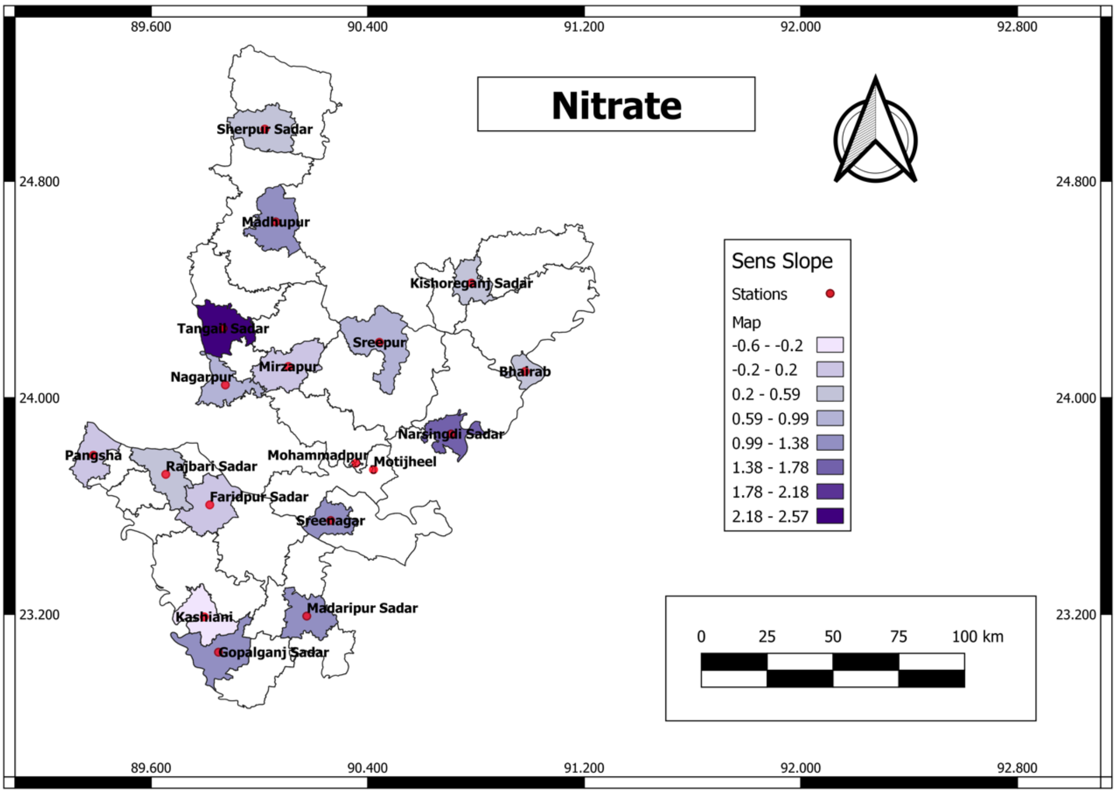
BICARBONATE



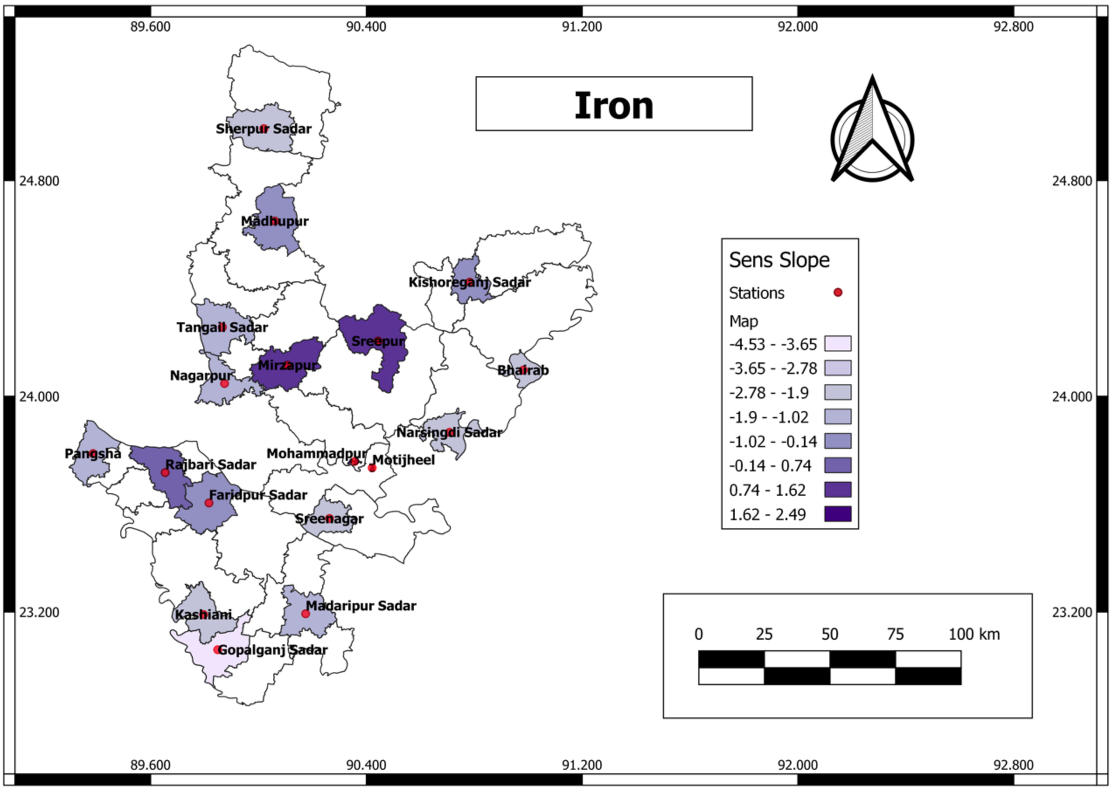
SULPHATE



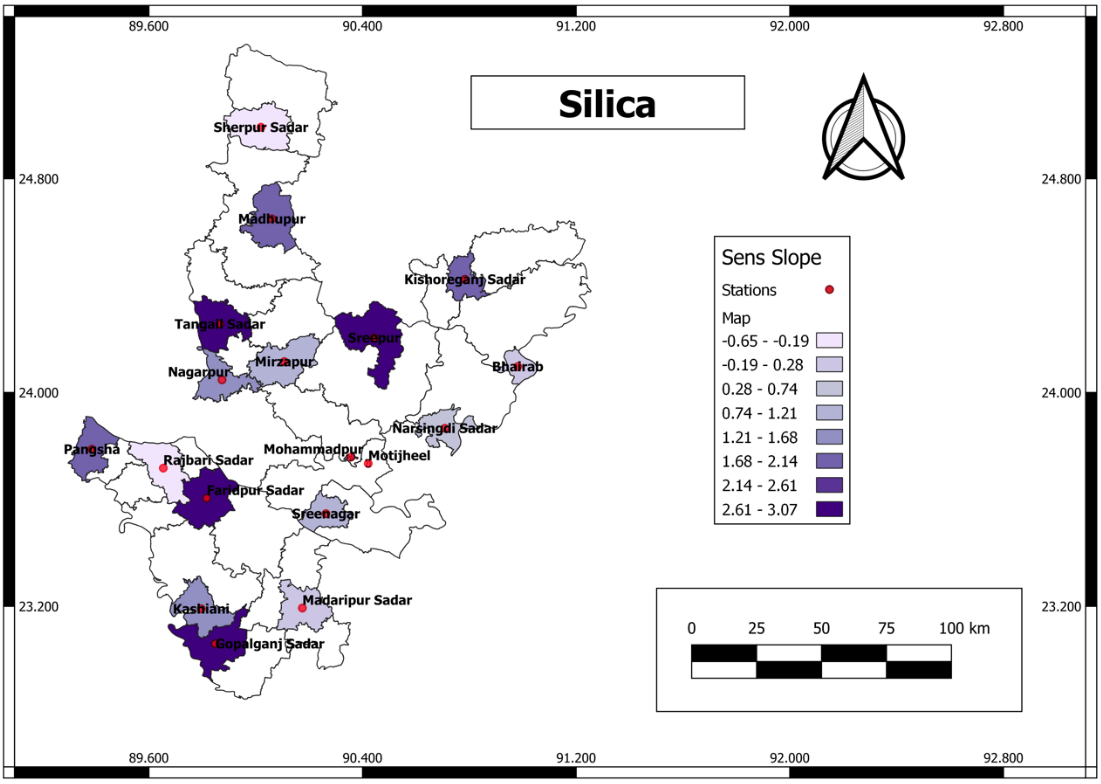
NITRATE



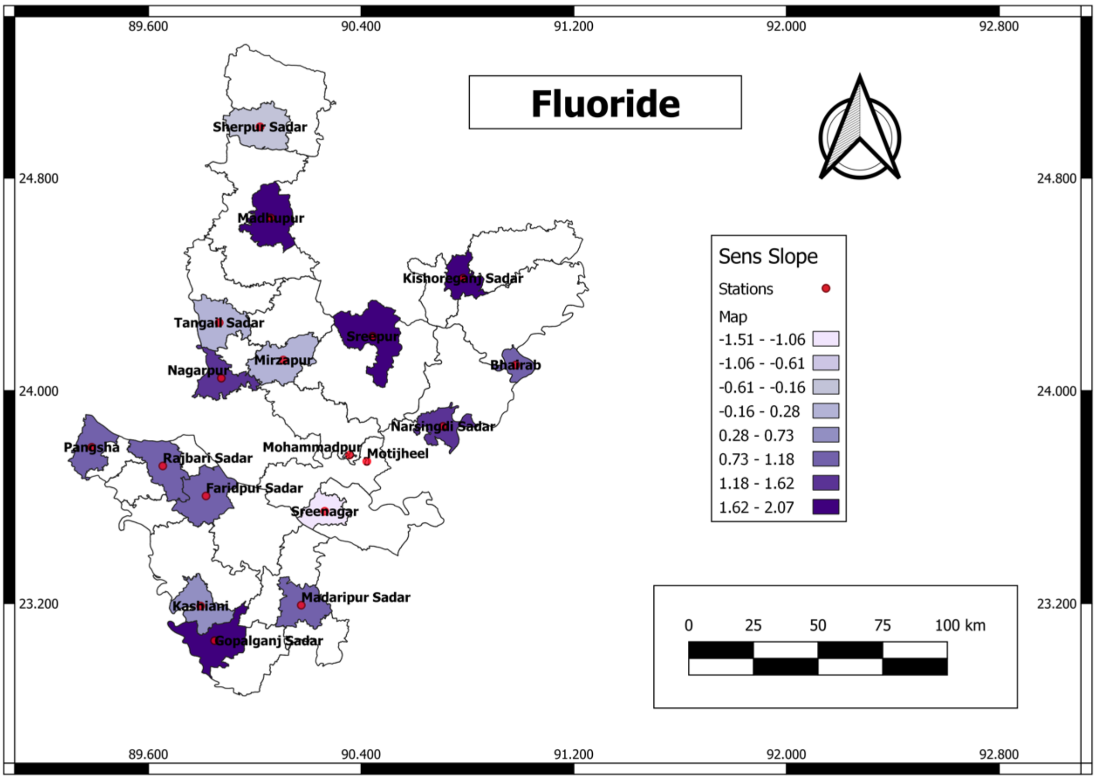
IRON



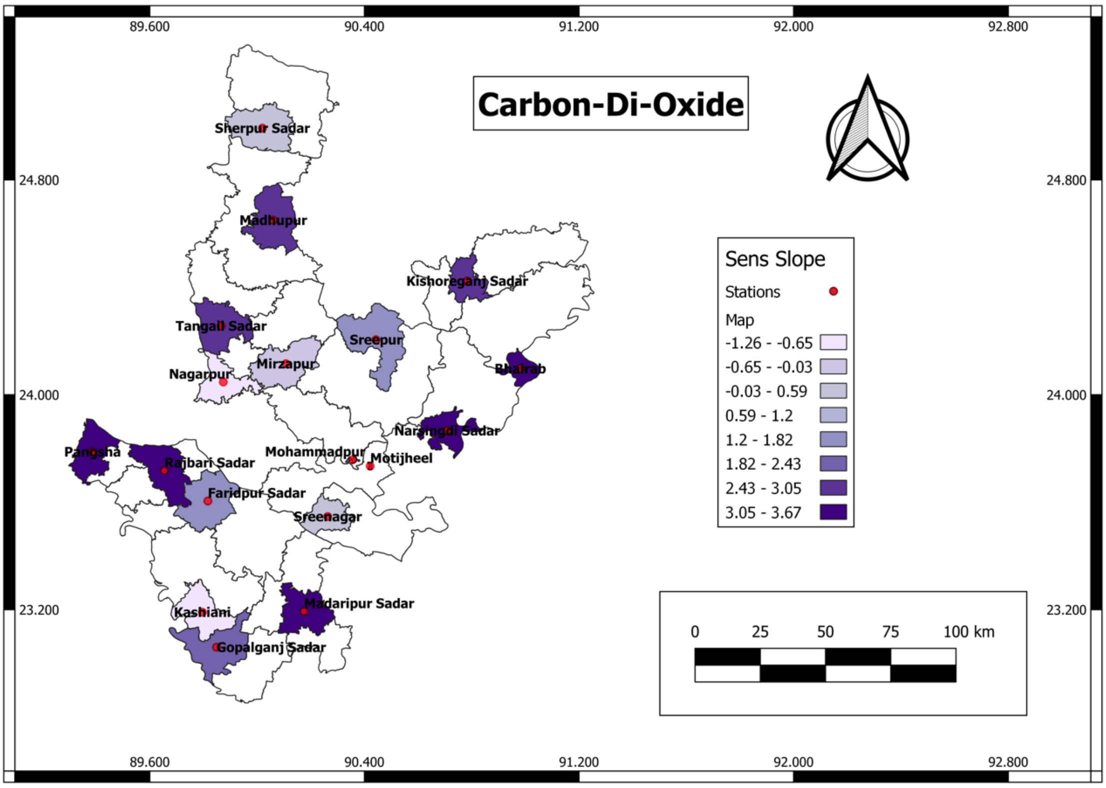
SILICA



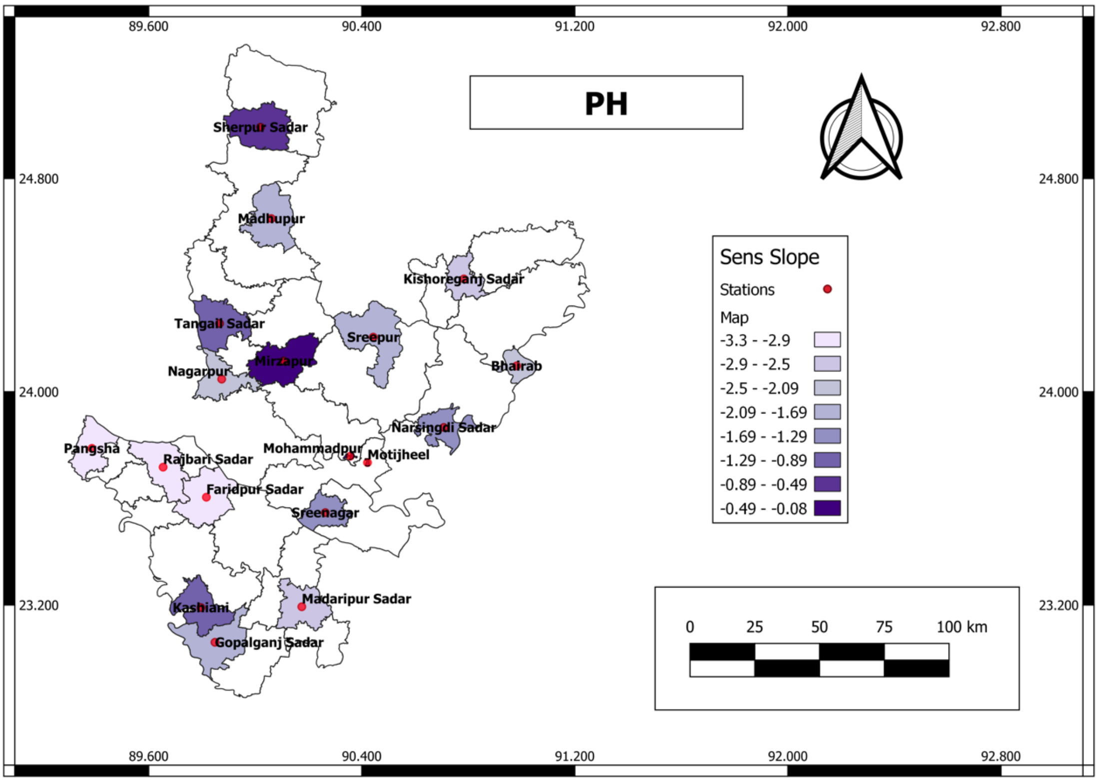
FLUORIDE



CARBONDIOXIDE



PH



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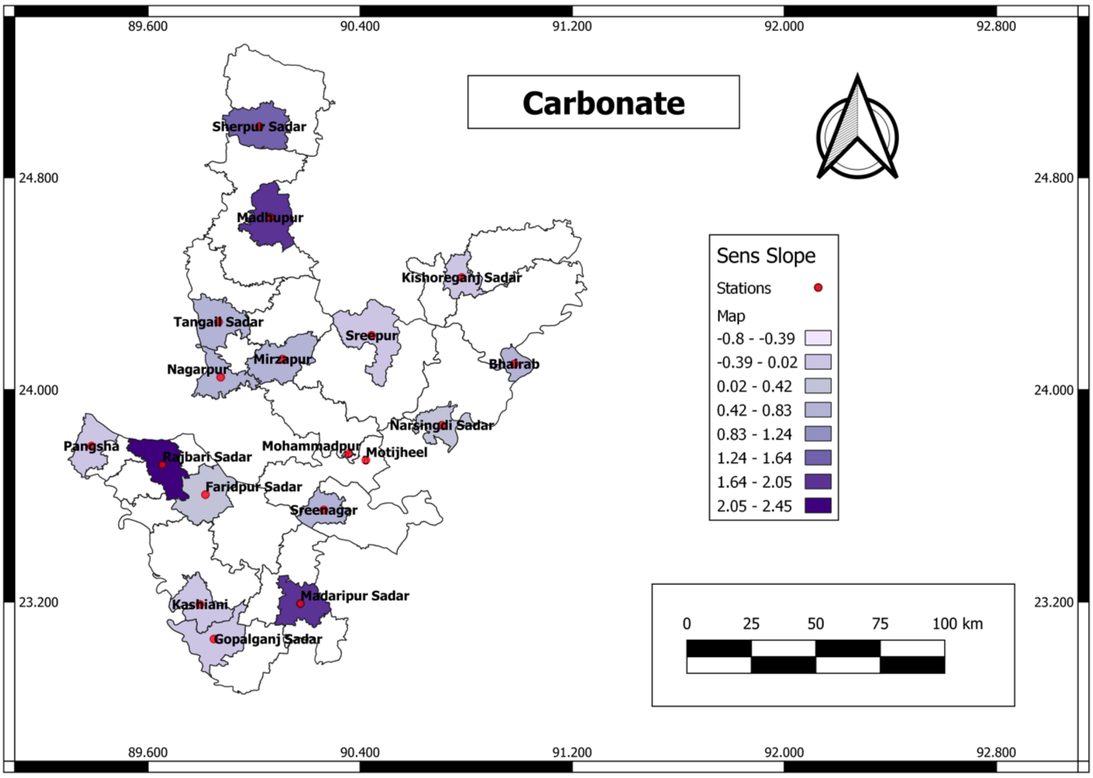
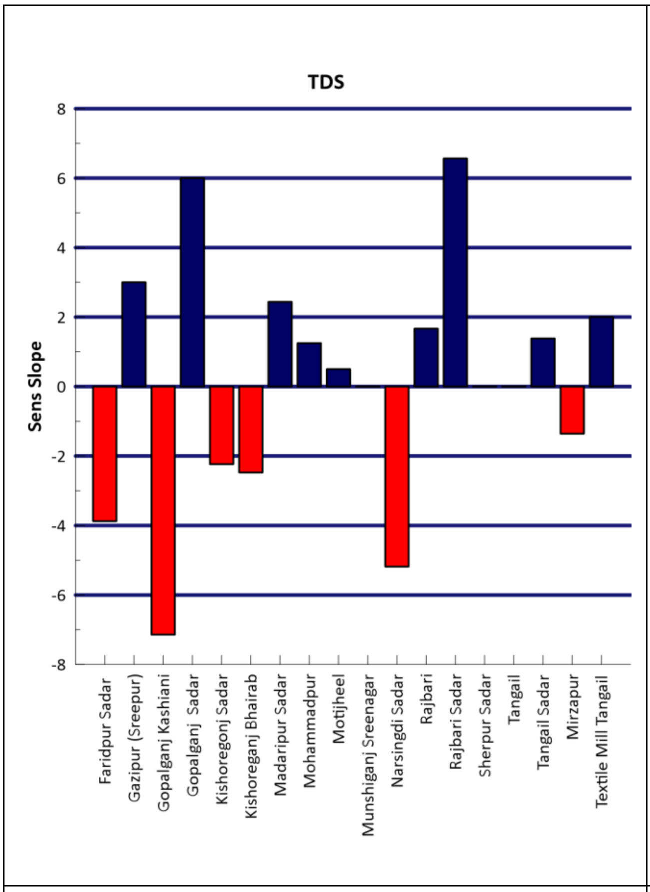
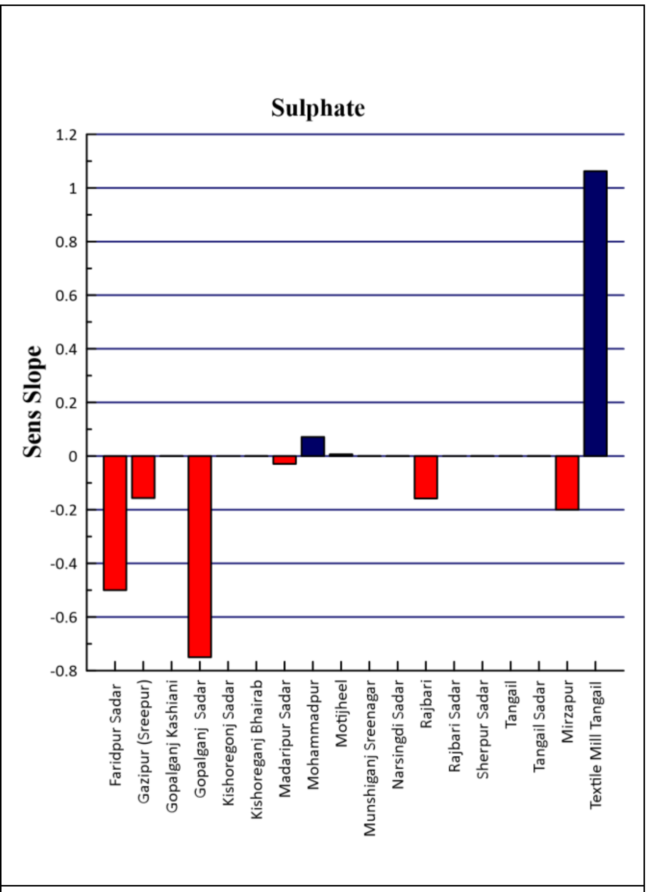
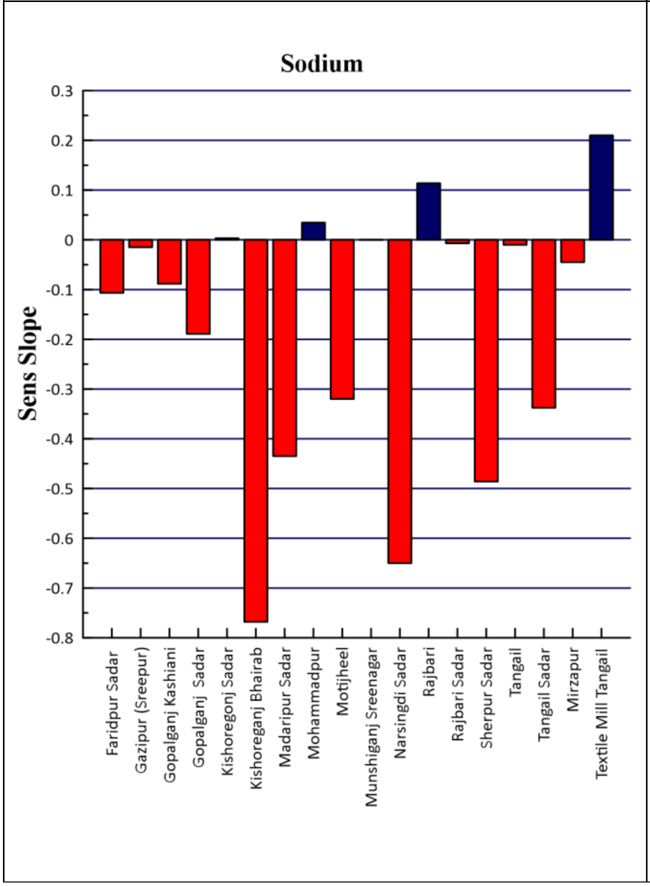
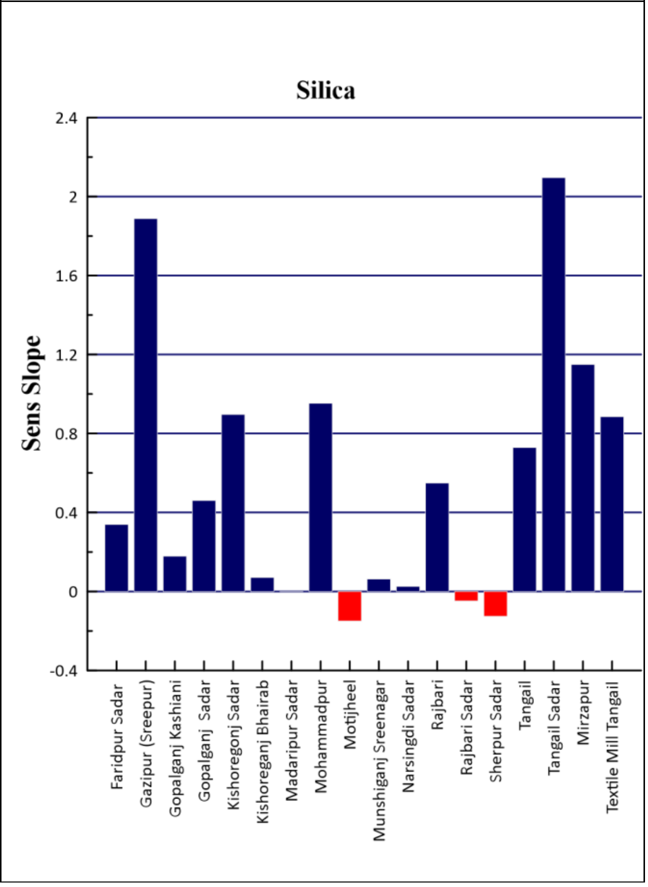

Carbonate
Sens Slope
Stations
Map
-0.8 - -0.39
-0.39 - 0.02
0.02 - 0.42
0.42 - 0.83
0.83 - 1.24
1.24 - 1.64
1.64 - 2.05
2.05 - 2.45
0 25 50 75 100 km
89.600 90.400 91.200 92.000 92.800
24.800 24.000 23.200
Sherpur Sadar
Madhupur
Kishoreganj Sadar
Tangail Sadar
Sreepur
Mirzapur
Nagarpur
Bhairab
Narsingdi Sadar
Pangsha
Rajbari Sadar
Mohammadpur
Motijheel
Faridpur Sadar
Sreenagar
Kashiani
Madaripur Sadar
Gopalganj Sadar

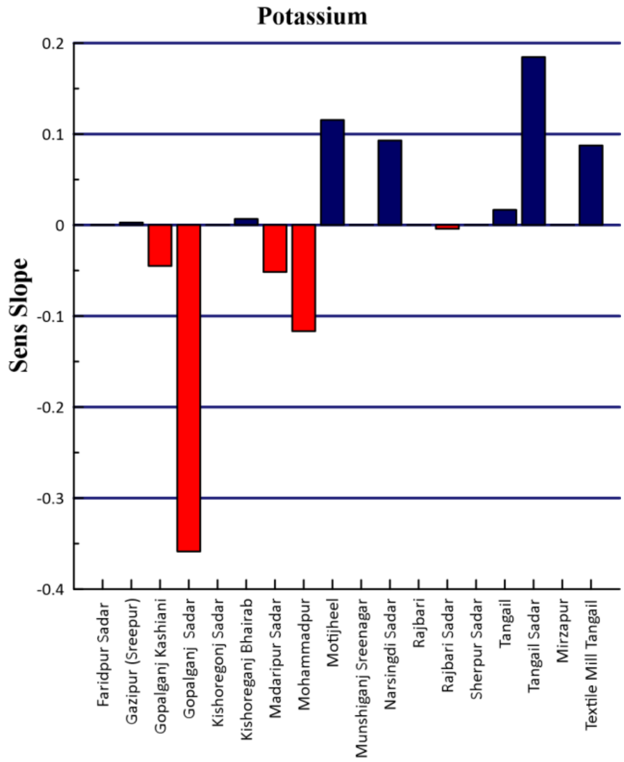
Bar Graph for Sen's Slope

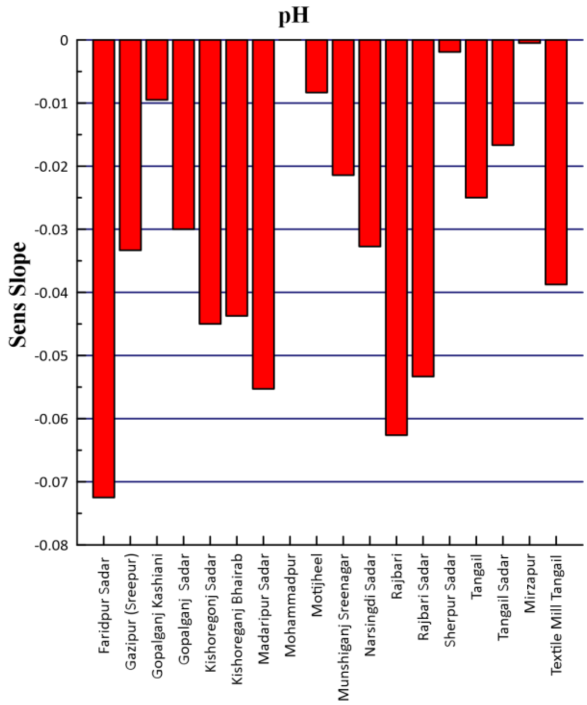


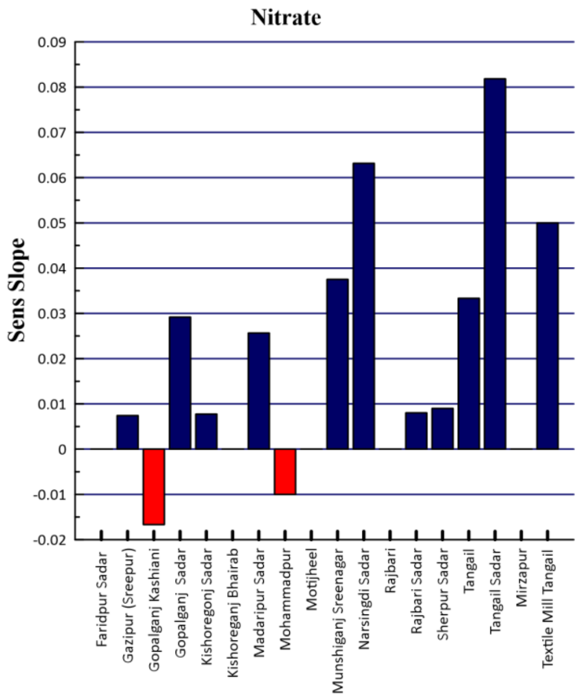


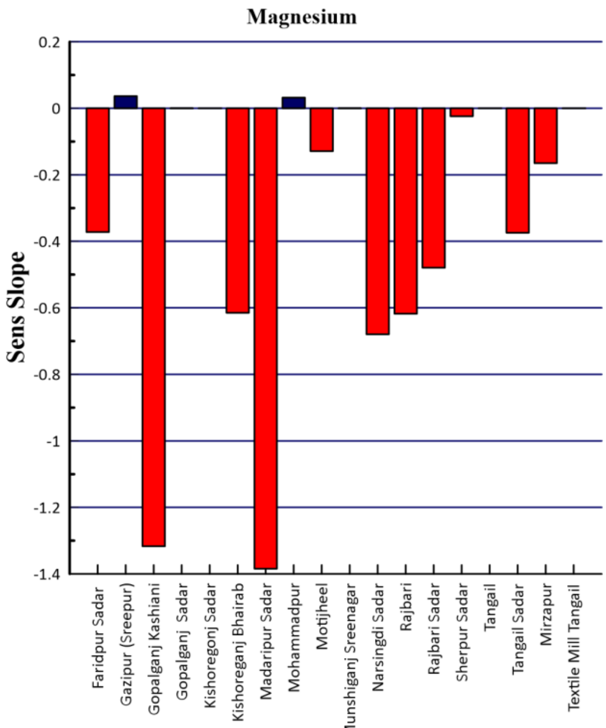


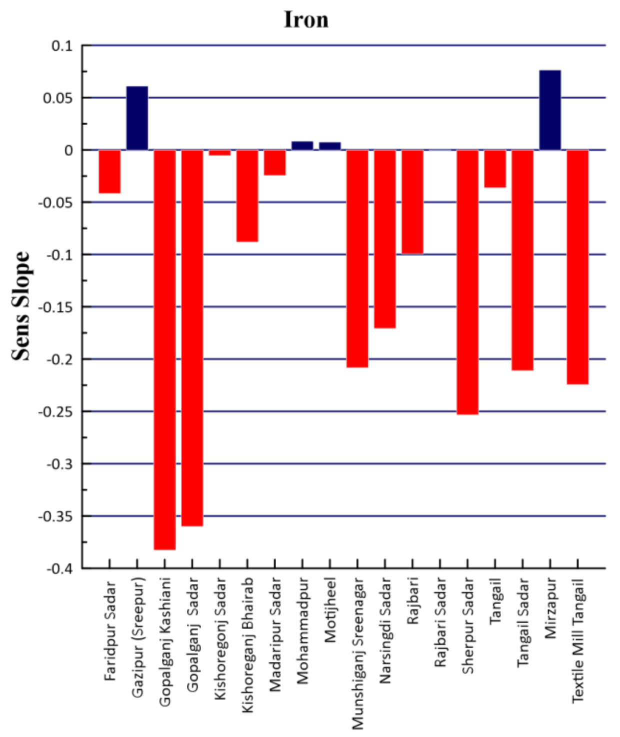


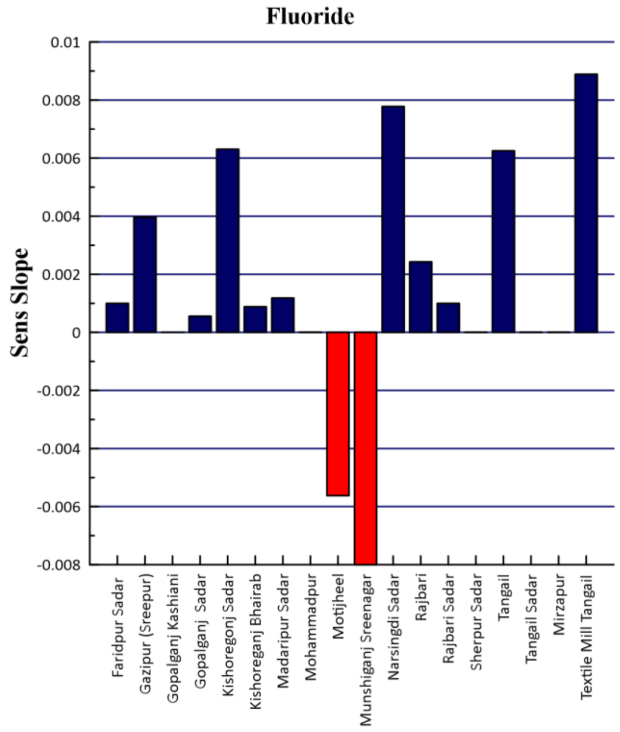

Potassium
Sens Slope
0.2
0.1
0
-0.1
-0.2
-0.3
-0.4
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail

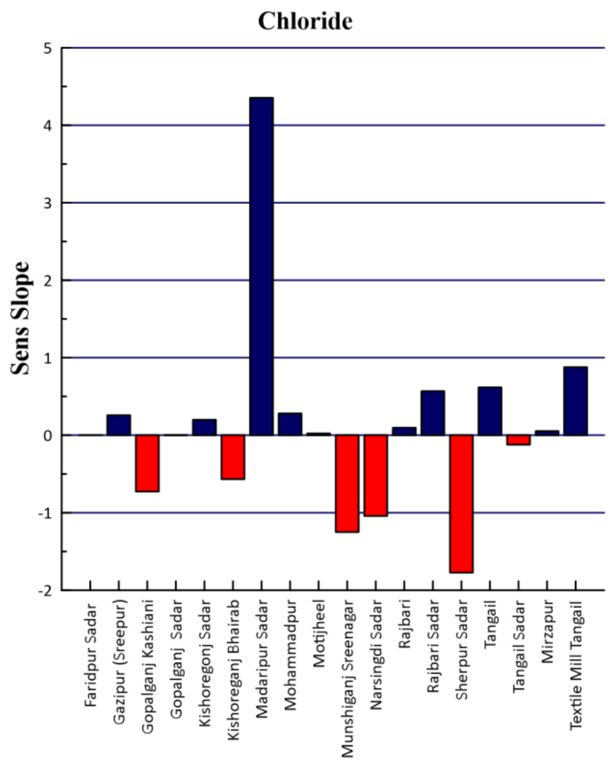

pH
Sens Slope
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.06
-0.07
-0.08
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail

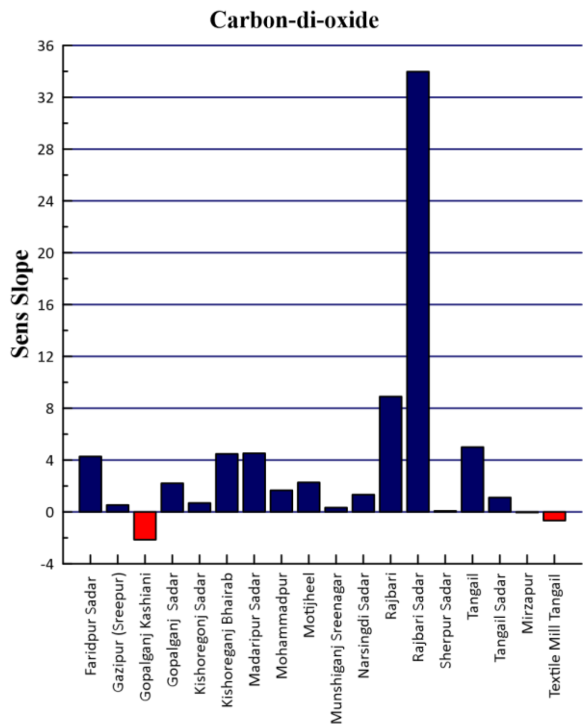

Nitrate
Sens Slope
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail

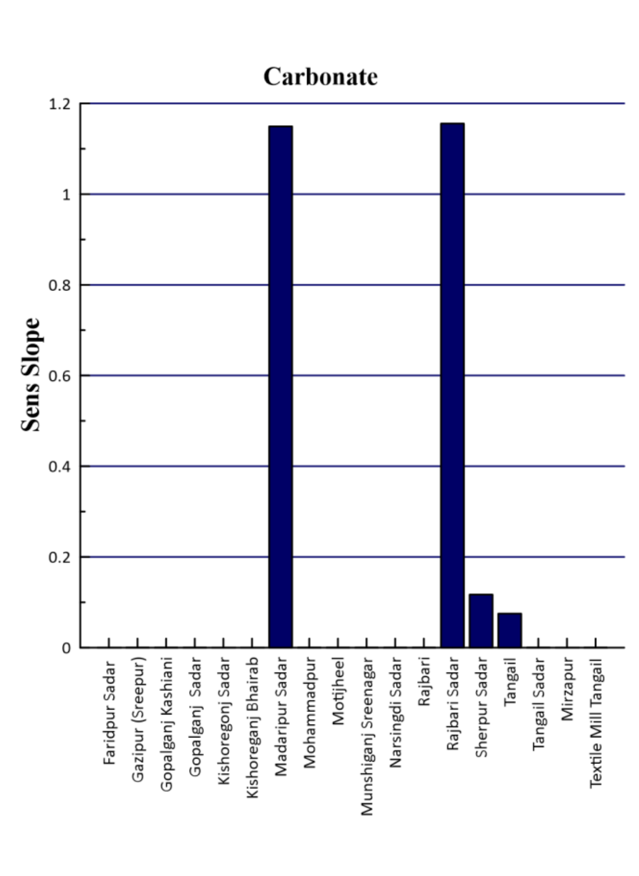

Magnesium
Sens Slope
0.2
0
-0.2
-0.4
-0.6
-0.8
-1
-1.2
-1.4
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail

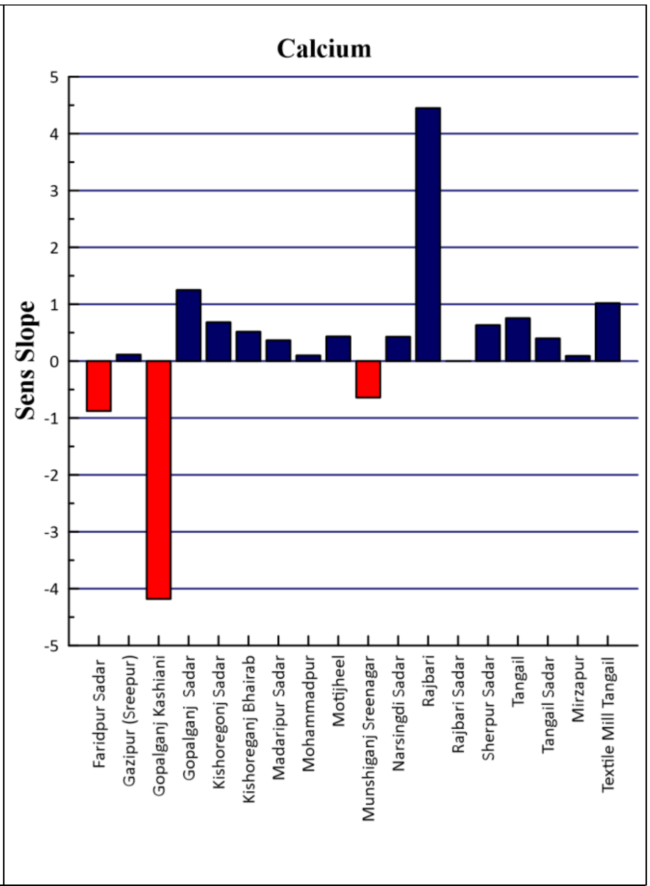

Iron
Sens Slope
0.1
0.05
0
-0.05
-0.1
-0.15
-0.2
-0.25
-0.3
-0.35
-0.4
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail

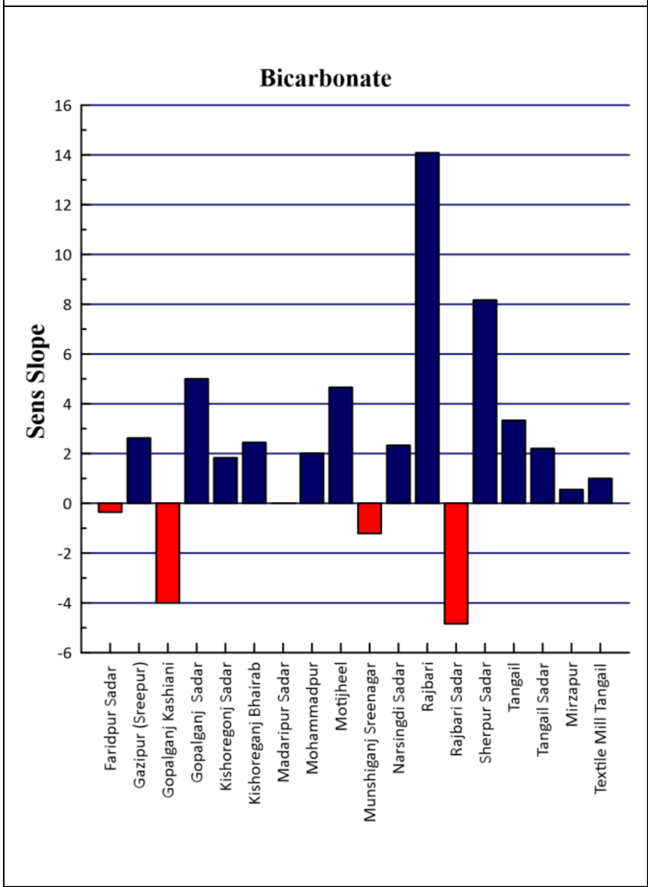

Fluoride
Sens Slope
0.01
0.008
0.006
0.004
0.002
0
-0.002
-0.004
-0.006
-0.008
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail


Chloride
Sens Slope
5
4
3
2
1
0
-1
-2
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail


Carbon-di-oxide
Sens Slope
36
32
28
24
20
16
12
8
4
0
-4
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail


Carbonate
Sens Slope
1.2
1
0.8
0.6
0.4
0.2
0
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail


Calcium
Sens Slope
5
4
3
2
1
0
-1
-2
-3
-4
-5
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
Sherpur Sadar
Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail


Bicarbonate
Sens Slope
16
14
12
10
8
6
4
2
0
-2
-4
-6
Faridpur Sadar
Gazipur (Sreepur)
Gopalganj Kashiani
Gopalganj Sadar
Kishoregonj Sadar
Kishoreganj Bhairab
Madaripur Sadar
Mohammadpur
Motijheel
Munshiganj Sreenagar
Narsingdi Sadar
Rajbari
Rajbari Sadar
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Tangail
Tangail Sadar
Mirzapur
Textile Mill Tangail