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# Groundwater quality mapping of Singrauli district using ArcGIS

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## Abstract

Singrauli district, which is in central India, is renowned for its extensive natural riches and vibrant industrial activity. The present study includes a comprehensive investigation on the spatial distribution and fluctuations of major physicochemical parameters, namely magnesium (Mg), chloride (Cl), and fluoride (F), in the groundwater of the Singrauli district. Understanding these characteristics is critical due to their potential impact on water quality and human health. The data needed for this study came from two distinct sources. The Central Groundwater Board website provided data from 2010 to 2018, while the Madhya Pradesh Groundwater Yearbook provided data for 2019-2020. This dataset was linked into ArcGIS, a Geographic Information System (GIS) application, allowing for the creation of thematic maps and spatial patterns that provide significant insights into the spatial distribution of certain parameters. Mg conc. values were within the permissible limit, that is 100 milligram litre$^{-1}$ except the max value that was observed at the location marked by the coordinates 24.067, 82.629 in the year 2012. At most places in the study area the conc. of chloride in the groundwater was found to be within the permissible limit. Maximum value of Fluoride conc. was 3.8 mg/l at the location marked by coordinates 24.233,82.377 (Lat., Long.) in the year 2016. The reason for this unusually high level of F conc. in the groundwater of Singrauli may be due to human activities like coal mining and leaching from the waste generated from the various power plants, etc.

**Keywords:** Singrauli; Groundwater quality; Spatial maps; ArcGIS; Magnesium; Fluoride; Chloride

## 1. Introduction

The quality of water and its availability have become an important global concern as an outcome of a growing population growth in industrial and agricultural development, and present climate change contributes to alterations in precipitation patterns [1].

Various manmade and natural actions, such as irrigation systems and methods, the field of geology and local climate, are reducing water quality. Fast urbanization and industrialization leads to a deterioration of surface and ground water quality [2].

Groundwater is significant not just for its long-term viability but also for its perpetual high efficiency [3].

Groundwater is one of the most significant natural and plentiful resources, in addition to being one of the primary sources of water supply globally. Water quality is a major concern for humans because it is directly tied to the health of people [4].

Subsurface geochemical techniques human activities, regional surface waters, the process of precipitation and replenished water quality all influence ground water quality. Changes in groundwater quality are primarily caused by changes in the chemical makeup and source of recharged water, as well as by human and hydrologic influences.

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Pollution of the water supply has an impact on water quality, as well as hygiene, economic growth, and social capital, as well as risks to mankind and other organisms [5][6].

While groundwater resources serve an important role in meeting the water needs in regions that are arid or semi-arid, a lot of them are being depleted due to exploitation [7].

Groundwater has been an essential supply of drinking water for the last twenty years because of the growing need for water, which leads to water scarcity; however, the level of groundwater is steadily declining due to excessive misuse; therefore, it is critical to begin studies related to ground water qualification and quantification, which are the primary goals for planning for its handling and usage [8].

Constant and adequate supplies of water for drinking from underground water bodies are critical for long-term farming, manufacturing, and home use throughout extensive semi-arid parts of India [9].

Groundwater drinking water problems are becoming increasingly serious throughout the country. Managing development in critical wetland areas especially in dry and semi-arid regions in India, entails both salinization and abuse of agricultural chemicals. Tracking of Fluoride and Nitrate concentrations and patterns in aquifers for farming, industrialized, and completely polluted areas is vital, and contamination standards must be improved [10].

Water quality is determined by its biological, chemical, and physical qualities. Until its use in many applications such as industrial, recreational, agricultural, and drinking is required [11].

The appropriate utilization of groundwater, that is a valuable but diminishing natural asset, necessitates an organized strategy of tapping utilizing current techniques. Advanced computerized and effective water management innovations have emerged, with RS, GIS, and GPS playing an important part [12].

GIS "Geographic Information System" technology is always evolving, and it requires enhanced processing of data and specialist solutions for integrated models of environmental simulation. Advances in accessing data and generation methods such as the World Wide Web, GPS, and satellite imagery [13].

GIS can be a helpful instrument to create solutions regarding water supply worries, such as comprehending the natural world, controlling floods, assessing water accessibility, and analyzing water quality [14].

Understanding the physicochemical physical distribution and groundwater depth is critical for water extraction and administration [15].

Water quality parameters such as suspended matter, turbidity, blooms of algae, chlorophyll, and the amount of minerals in bodies of water such as groundwater are evaluated at less expense and with more precision using improved spatial and spectral resolution sensors and Geographic Information Systems modeling approaches [16].

The Singrauli area in India illustrates the issues faced by fast growth in urbanization and industrialization. This region has undergone an exponential rise throughout the years as a result of growth in industry, mining operations, and growth in cities. Such changes invariably impact the natural environment and create reasonable worries regarding groundwater quality. Given that groundwater is the main source of water for drinking for many people in Singrauli, evaluating and protecting its quality has become essential.

## 2. Material and methods

The methodology section describes the method used to analyze groundwater quality in the Singrauli region, with an emphasis on magnesium, fluoride, and chloride parameters. The research technique incorporates primary and secondary data sources, makes use of modern Geographic Information Systems (GIS) technology, and covers the years 2010 through 2020.

### 2.1. The importance of groundwater quality assessment

Groundwater quality assessment is a difficult task motivated by a number of compelling causes, including:

- Scientific Advances: Geospatial technology and data analytic advancements offer new tools for evaluating groundwater quality. This study adds to the body of scientific information and demonstrates the potential of cutting-edge technology in environmental research.
- Resource Management: The sustainable management of the resources of groundwater is essential for both the social and economic stability of the region. Groundwater quality must be protected and maintained to ensure a reliable and long-term source of freshwater.
- Policy Development: Authorities rely on data about groundwater quality to make informed choices. Policymakers need an extensive knowledge of the distribution and temporal patterns of essential water quality indicators for them to effectively carry out land use planning, industrial management, and management of resources policies.
- Environmental Protection: Groundwater is vital for ensuring the preservation of ecological balance in ecosystems. Groundwater environments that are healthy maintain biodiversity, contribute to environmental sustainability, and guarantee the survival of numerous species.
- Public Health and Safety: A regular supply of safe and clean drinking water is crucial for the well-being of the public. Waterborne infections can be propagated by contaminated groundwater, presenting long-term health threats to populations.

*Research objectives*

This research paper is driven by a number of main objectives:

- To assess and illustrate the regional and temporal trends in groundwater quality parameters in Singrauli, specifically magnesium, chloride, and fluoride, from 2010 to 2020.
- To identify regions where groundwater quality has improved or degraded over time.

By achieving these goals, this research hopes to significantly advance our understanding of groundwater quality assessment, highlight the critical role of geospatial technology in environmental research, and highlight the urgent need for proactive measures to protect this critical natural resource in rapidly industrializing and urbanizing regions like Singrauli.

### 2.2. The role of geospatial analysis

In the context of Singrauli, geospatial technology, particularly Geographic Information Systems (GIS) such as ArcGIS, emerges as a useful tool for analyzing groundwater quality. Researchers can use ArcGIS to generate precise spatial maps displaying the geographic distribution patterns and trends of crucial groundwater quality indicators throughout time. This method provides a comprehensive perspective of the Singrauli hydrochemical landscape, allowing for the identification of areas of concern, potential pollution sources, and temporal fluctuations.

### 2.3. Study area

Geographical Coordinates:

- Latitude: The Singrauli district is located between 23.5°N and 24.5°N latitude.
- Longitude: It is located between 81.5°E and 82.5°E longitude.
- Northern Boundary: Singrauli district's northern boundary is continuous with the state of Uttar Pradesh.
- Eastern Boundary: The district shares its eastern boundary with the state of Chhattisgarh.
- Southern Boundary: The southern border continues into Madhya Pradesh's center region.

The western boundary comprises sections of the Uttar Pradesh district of Sonbhadra.

The Singrauli district's topography ranges from flat plains to slightly sloping slopes. The area is located in the Gondwana basin and is known for its coal-rich environment, the confluence of the Son and Rihand rivers, and the Son River itself.

- Hydrography: The Rihand River, produced by the confluence of the Son and Rihand Rivers, and the Son River itself are major rivers that run through the area.
- Key Geological Characteristics: The area is well-known for its Gondwana sedimentary rock formations, which contain significant coal reserves. The geological makeup has a significant impact on groundwater quality and availability. These geographical data are vital to knowing about the Singrauli district's location and characteristics, which is essential to the study's focus on the spatial mapping of physicochemical factors in the area's groundwater.

The groundwater quality data of mainly following locations (Lat, Long) were used for the creation of spatial maps using Arc GIS software:

Banjari (24.088,81.93), Bargawan(24.196,82.456), Betaha Dand(24.239,82.377), Bharra (24.383,82.26), Bharseda (24.078,81.963), Chamari Dol (24.001,82.106), Chaura (24.011,82.472), Deosar (24.319 82.304), Gaderiya (24.156,82.486), Jamgadi (24.04,82.318), Jattha Tola (24.047,82.256), Kachani (24.082,82.592), Karthua (24.395,82.244), Kohara Khoh (24.268,82.343), Koyal Khunth (23.946,82.485), Mara (23.897,82.503), Papal Khera (24.12,81.934), Parasi (24.04,82.041), Parsauna New (24.089,82.558), Sarai (24.04,82.204)

## 2.4. Data collection

The data collection procedure is critical to the assessment of groundwater quality. It entails acquiring data sources that are necessary for the study.

### *2.4.1. Data source (2010-2018)*

The CGWB, which keeps a comprehensive record of water quality measurements, released groundwater quality data from 2010 to 2018. These statistics include important factors such as chloride, magnesium and fluoride.

### *2.4.2. Data source (2019-20)*

MP Groundwater Yearbook: Groundwater quality data for 2019 and 2020 were acquired from the MP Groundwater Yearbook. This source is useful for filling in the data gaps and completing the assessment.

## 2.5. Creation of excel sheets of data

Data pre-processing is critical for ensuring data accuracy and reliability. This phase entails creating excel sheets in MS-Excel. Several excel sheets were created using data from the CGWB website and the MP groundwater Yearbooks. The data pertaining to the levels of the specified quality indicators for various locations and years were suitably structured in order to construct year-by-year excel sheets from 2010 to 2020. It was done to create spatial maps of groundwater quality parameters year by year in order to visually portray the variation of groundwater quality in the Singrauli district with the help of ArcGIS.

## 2.6. Geospatial analysis using ArcGIS

Geospatial analysis is an important part of this study. A complete examination of groundwater quality in Singrauli is carried out using ArcGIS software.

### *2.6.1. Spatial mapping*

ArcGIS is used to build spatial maps that show the distribution of groundwater quality parameters such as magnesium, chloride, and fluoride throughout the Singrauli region. Various maps clearly depict the spatial volatility of various elements.

All of the information was entered into a spatial database, and IDW was used to generate spatial versions of the findings. Arc GIS software (version 10.8.2) was used to make the maps. IDW interpolation is based on the assumption that the amount of distance or angular orientation between sampling points exhibits a spatial correlation that can be used to account for surface alteration. Using the IDW tool, the output value for each site is determined by fitting a mathematical function to a set number of points or all points within a given radius. In two-dimensional situations, the basic formula for interpolation using Inverse Distance Weighted (IDW) is as follows:

$$w(x,y) = \sum_{i=1}^{N} iw_i \text{ ............... } (1)$$

$$i = \frac{(\frac{1}{d})^p}{\sum_{i=1}^{N}(\frac{1}{d})^P} \text{ ............. } (2)$$

where w(x,y) is the forecasted value at (x,y), N is the number of closest known points surrounding (x,y), $w_i$ are the weights assigned to every known point value $w_i$ at ($x_i$,$y_i$), di are the 2-D Euclidean distances between each ($x_i$,$y_i$) and (x,y), and p is the experiment that influences the weighting of $w_i$ on w [17]. The benefit of IDW is that it is efficient and intuitive, so that IDW method is widely used in spatial interpolation of ground water quality [18].

## 3. Results and discussion

### 3.1. Magnesium

The highest Magnesium levels was 60.83 milligram litre$^{-1}$ in the groundwater of the Singrauli district in 2010, and it was found at the location identified by the coordinates 24.0833,82.560 (Latitude, Longitude). While the lowest concentration of Magnesium was 12.21 mg/l observed at the location marked by coordinates 24.383,82.259 (Latitude, Longitude). Moreover, the average Magnesium concentration in the Singrauli region groundwater was found out to be 22.76 mg/l. Similarly, for the year 2011, highest Magnesium concentration was 13.49 mg/l at 24.067,82.6291 (Latitude, Longitude), lowest Magnesium concentration was 2.51 mg/l at 24.316,82.304 (Latitude, Longitude), and average Magnesium concentration was 8.58 mg/l in Singrauli region.

For years 2012-20, the findings can be tabulated as follows:

**Table 1** Values of concentration of Magnesium in Singrauli District for the years 2012-20

| Year | Max. Value of Magnesium Conc. (mg/l) | Max. Value observed at location (Latitude, Longitude) | Min. Value of Magnesium Conc. (mg/l) | Min. Value observed at location (Latitude, Longitude) | Average Value of Magnesium Conc. (mg/l) |
|---|---|---|---|---|---|
| 2012 | 105.79 | 24.067,82.629 | 31.62 | 24.083,82.560 | 48.44 |
| 2013 | 94.85 | 23.883,82.502 | 6.09 | 24.033,82.317 | 35.52 |
| 2014 | 41.36 | 24.233,82.377 | 7.3 | 24.033,82.317 | 19.95 |
| 2015 | 48.17 | 24.233,82.377 | 4.87 | 24.033,82.317 | 17.00 |
| 2016 | 24 | 24.033,82.203 | 0 | 24.383,82.259 | 12.88 |
| 2017 | 46.29 | 24.383,82.243 | 4.89 | 24.383,82.259 | 21.28 |
| 2018 | 52 | 24.082,82.592 | 4 | 24.04,82.318 | 18.1 |
| 2019 | 40 | 24.082,82.592 | 2 | 24.04,82.318 | 19.3 |
| 2020 | 34 | 23.897,82.503 | 9 | 24.319,82.304 | 17.36 |

### 3.2. Chloride

In the year 2010, the highest concentration of Chloride in the groundwater of Singrauli district was 75 mg/l, observed at the location marked by coordinates 24.183,82.455 (Latitude, Longitude). The location defined by the coordinates 24.383,82.259 (Latitude, Longitude) had the least amount of Cl concentration, which was 11 milligram litre$^{-1.}$ Moreover, the average Chloride concentration in the Singrauli region groundwater was found out to be 42.5 milligram litre$^{-1.}$ The location designated by coordinates 24.067,82.629 (Latitude, Longitude) had the highest Cl concentration in the Singrauli district's groundwater in 2011, which was 95 milligram litre$^{-1}$. Whereas, the area with the lowest Cl concentration— 11 milligram litre$^{-1}$—was identified at the coordinates 24.383,82.259 (Latitude, Longitude). Moreover, the average Chloride concentration in the Singrauli region groundwater was found out to be 46.67 milligram litre$^{-1}$. The area designated by coordinates 24.067,82.629 (Latitude, Longitude) had the highest Cl concentration in the Singrauli district's groundwater for the year 2012, which was 226.9 milligram litre$^{-1}$. Additionally, the lowest Cl concentration was found in a position with the coordinates 24.383,82.259 (Latitude, Longitude) and it was 17.73 mg litre$^{-1}$. Moreover, the average Chloride concentration in the Singrauli region groundwater was found out to be 70.92 milligram litre-1. For the year 2013, the highest concentration of Cl in Singrauli district's groundwater was 326 milligram litre-1, observed at the location marked by coordinates 24.067,82.629 (Latitude, Longitude). The location identified by coordinates 24.383,82.259 (Latitude, Longitude) had the lowest Chloride concentration, which was 11 milligram litre$^{-1}$. Moreover, the average Chloride concentration in the Singrauli region groundwater was found out to be 103.18 mg/l.

For years 2014-2020, the findings can be tabulated as follows:

**Table 2** Values of concentration of Chloride in Singrauli District for the years 2014-20

| Year | Max. Value of Cl Conc. mg/l) | Max. Value observed at location (Latitude, Longitude) | Min. Value of Cl Conc. (mg/l) | Min. Value observed at location (Latitude, Longitude) | Average Value of Cl Conc. In Singrauli District Groundwater (mg/l) |
|---|---|---|---|---|---|
| 2014 | 160 | 24.383,82.243 | 7 | 24.383,82.259 | 54.87 |
| 2015 | 355 | 24.383,82.243 | 2 | 24.383,82.259 | 54.12 |
| 2016 | 160 | 24,82.471 | 7 | 24.033,82.317 | 49.82 |
| 2017 | 233 | 23.883 82.502 | 7 | 24.383,82.259 | 50.8 |
| 2018 | 218 | 24.082,82.592 | 15 | 24.047,82.256 | 58.25 |
| 2019 | 177 | 24.082,82.592 | 5 | 24.04,82.318 | 46 |
| 2020 | 352 | 24.082,82.592 | 27 | 24.12,81.934 | 82.10 |

### 3.3. Fluoride

For the year 2010, the highest concentration of Fluoride in the groundwater of Singrauli district was 0.92 mg/l, observed at the location marked by coordinates 24.183,82.455 (Latitude, Longitude). The location designated by the coordinates 24.383, 82.259 (Latitude, Longitude) had the lowest F conc., which was measured at 0.16 milligram litre$^{-1}$. Moreover, the average Fluoride concentration in the Singrauli region groundwater was found out to be 0.428 mg/l. Similarly, for the year 2011, highest Fluoride concentration was 1.2 mg/l at 24.183,82.455 (Latitude, Longitude), lowest Fluoride concentration was 0.04 mg litre$^{-1}$ at 24.067, 82.629 ( Latitude, Longitude), and average F concentration was 0.337 mg/l in Singrauli region.

For years 2012-2020, the findings can be tabulated as follows:

**Table 3** Values of concentration of Fluoride in Singrauli District for the years 2012-20

| Year | Max. Value of Fluoride Conc.(mg/l) | Max. Value observed at location (Latitude, Longitude) | Min. Value of Fluoride Conc. (mg/l) | Min. Value observed at location (Latitude, Longitude) | Average. Value of Fluoride Conc. (mg/l) |
|---|---|---|---|---|---|
| 2012 | 2.04 | 24.317,82.304 | 0.53 | 23.883,82.502 | 1.05 |
| 2013 | 1.55 | 24.183,82.455 | 0.03 | 23.883,82.502 | 0.37 |
| 2014 | 1.32 | 23.883,82.502 | 0.1 | 24.033,82.041 | 0.56 |
| 2015 | 1.1 | 24.183,82.455 | 0.1 | 24.033,82.318 | 0.42 |
| 2016 | 3.8 | 24.233,82.377 | 0 | 24.267,82.3425 | 0.51 |
| 2017 | 1.43 | 23.883,82.502 | 0.09 | 23.933,82.485 | 0.55 |
| 2018 | 1.62 | 24.239 82.377 | 0.15 | 24.088,81.93 | 0.69 |
| 2019 | 1.95 | 24.239 82.377 | 0.15 | 24.001,82.106 | 0.50 |
| 2020 | 1.01 | 24.082 82.592 | 0.05 | 24.383,82.26 | 0.43 |

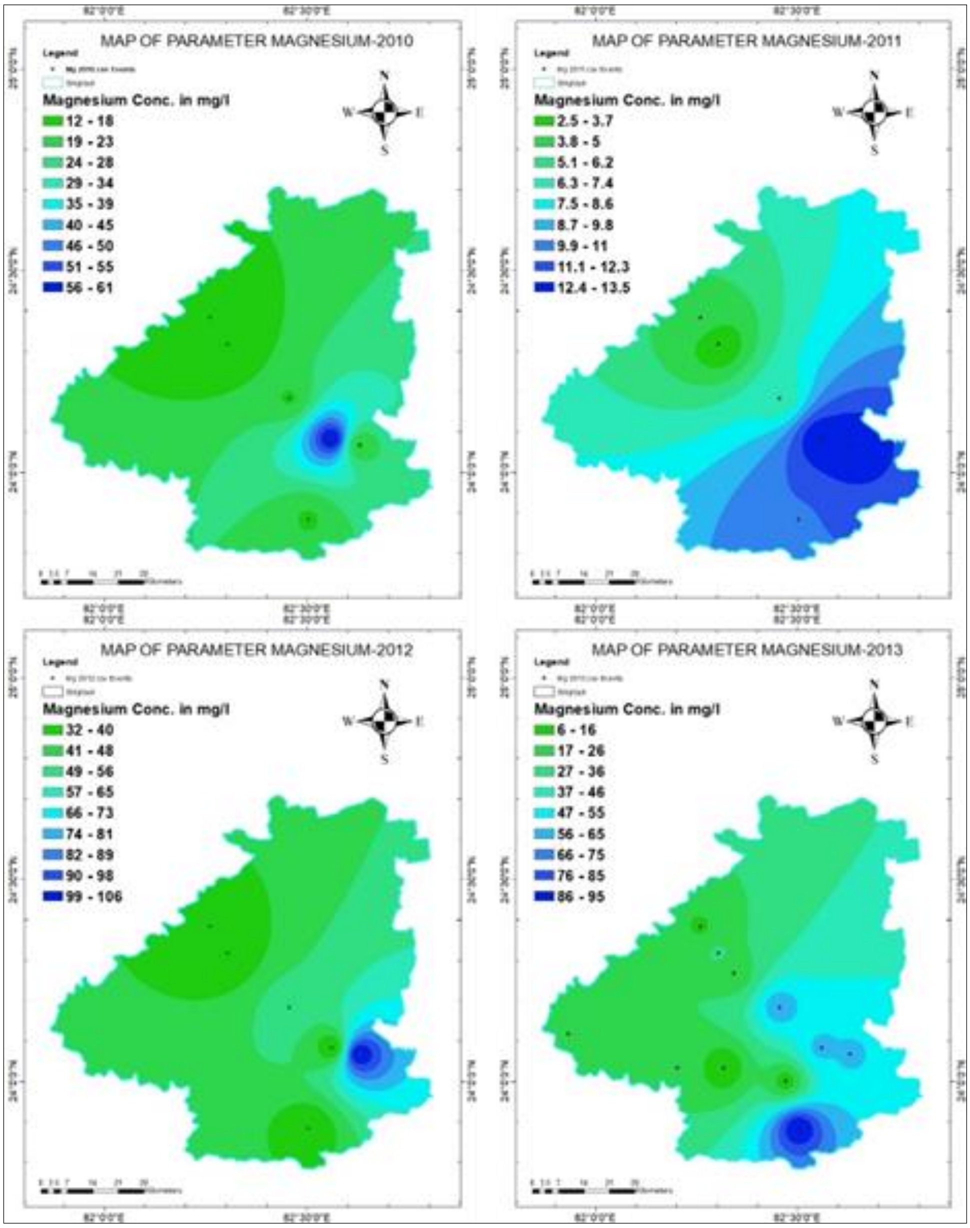


**Figure 1** Magnesium distribution in the area of study over the period 2010-13

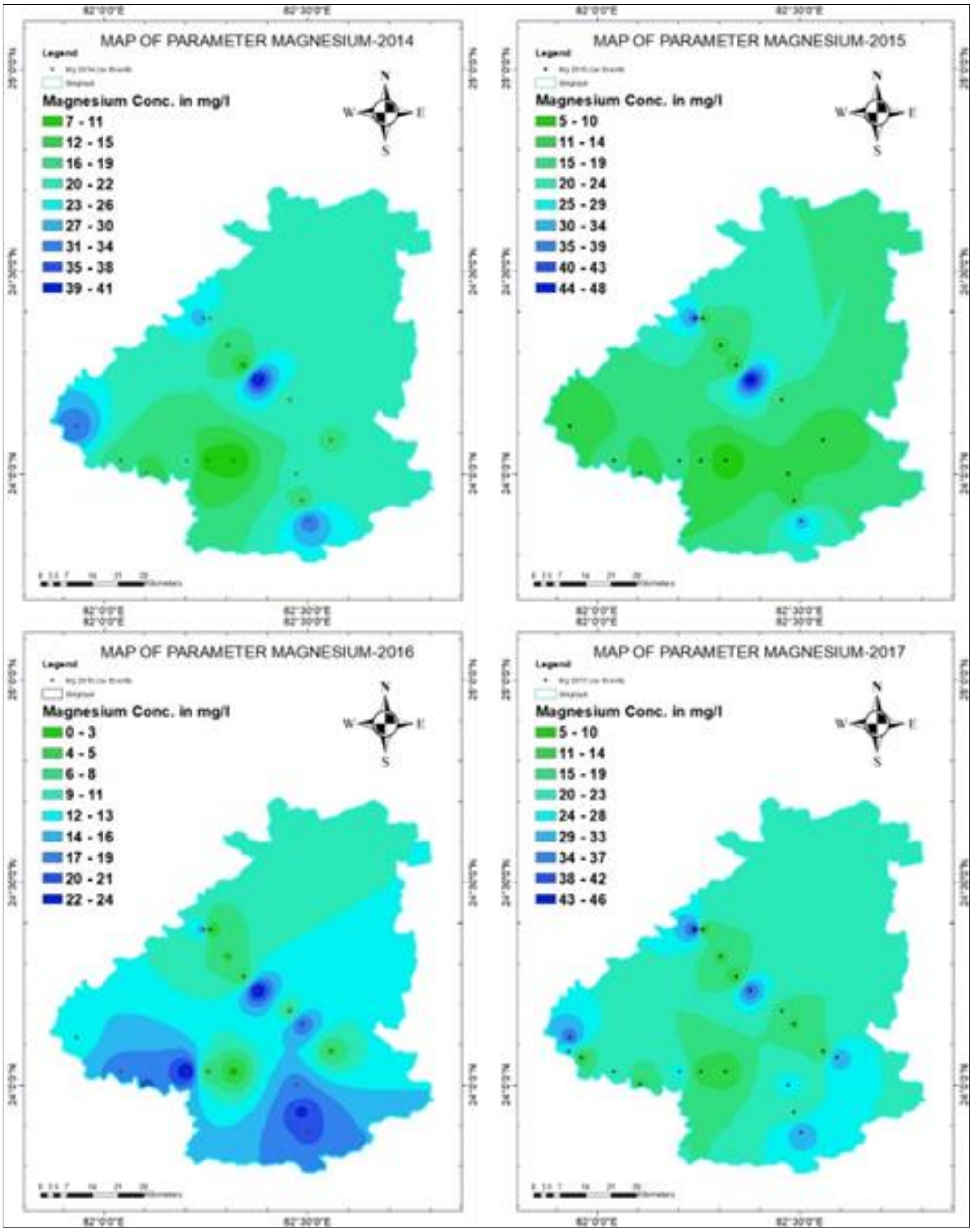


**Figure 2** Magnesium distribution in the area of study over the period 2014-17

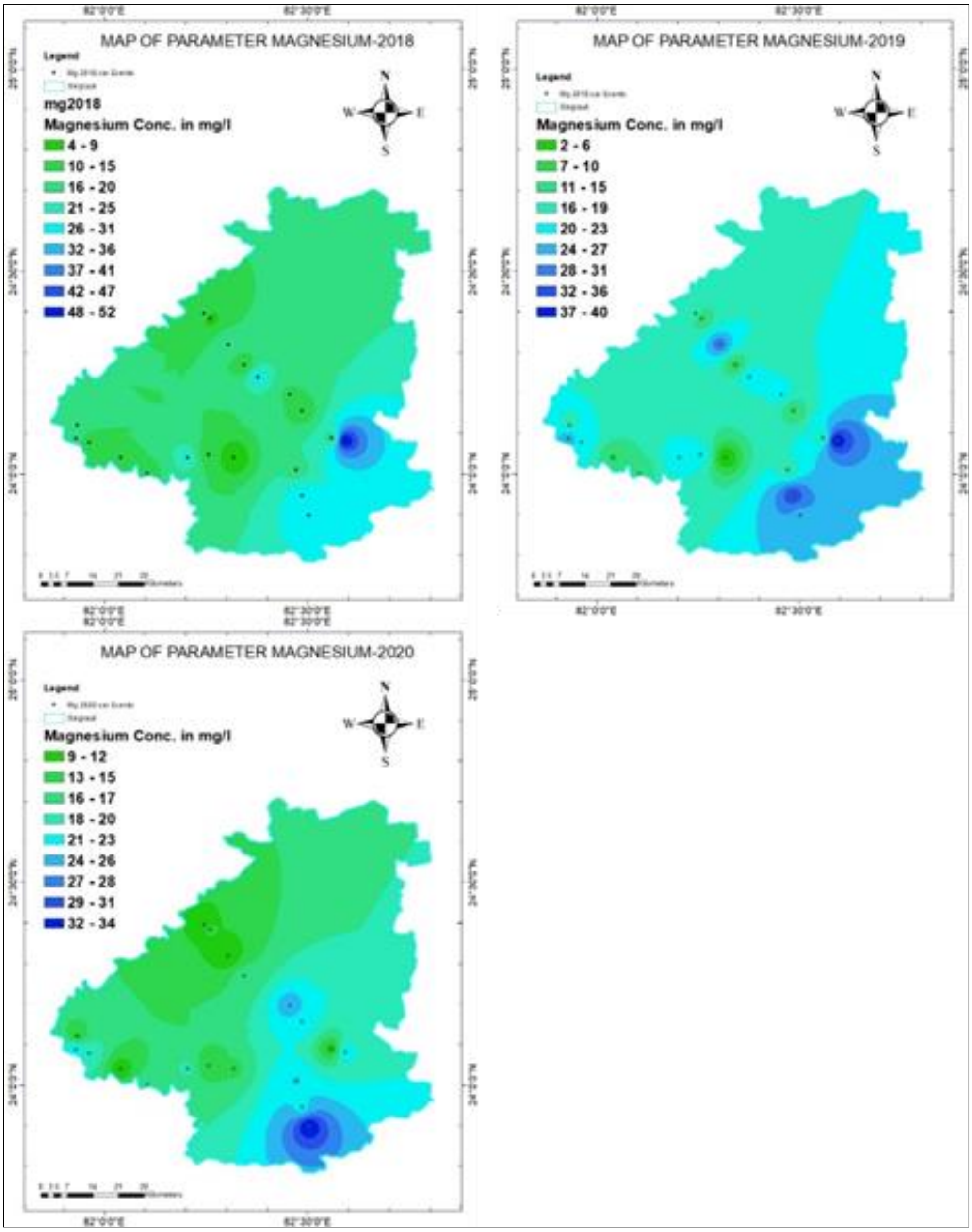


**Figure 3** Magnesium distribution in the area of study over the period 2018-20

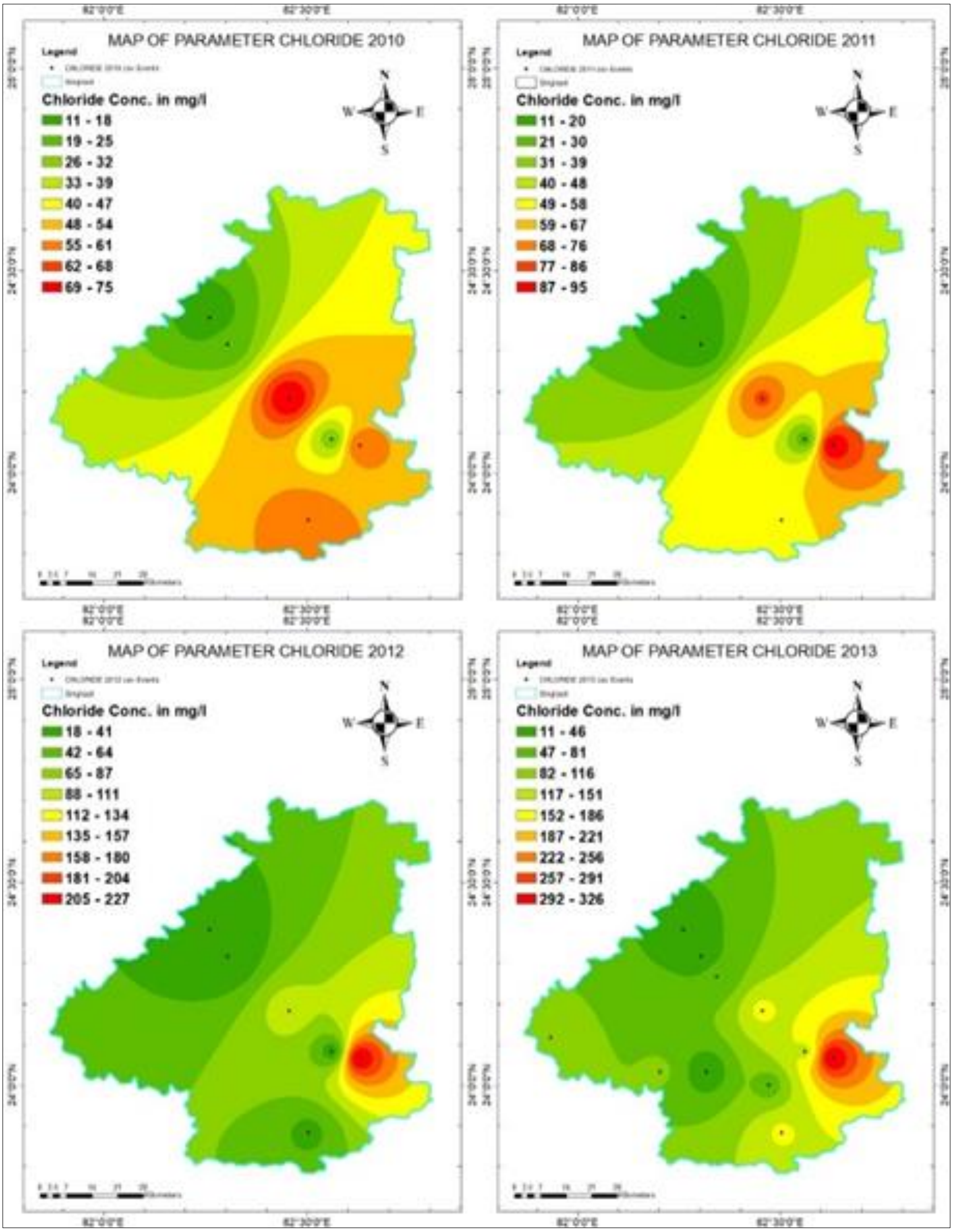


**Figure 4** Chloride distribution in the area of study over the period 2018-20

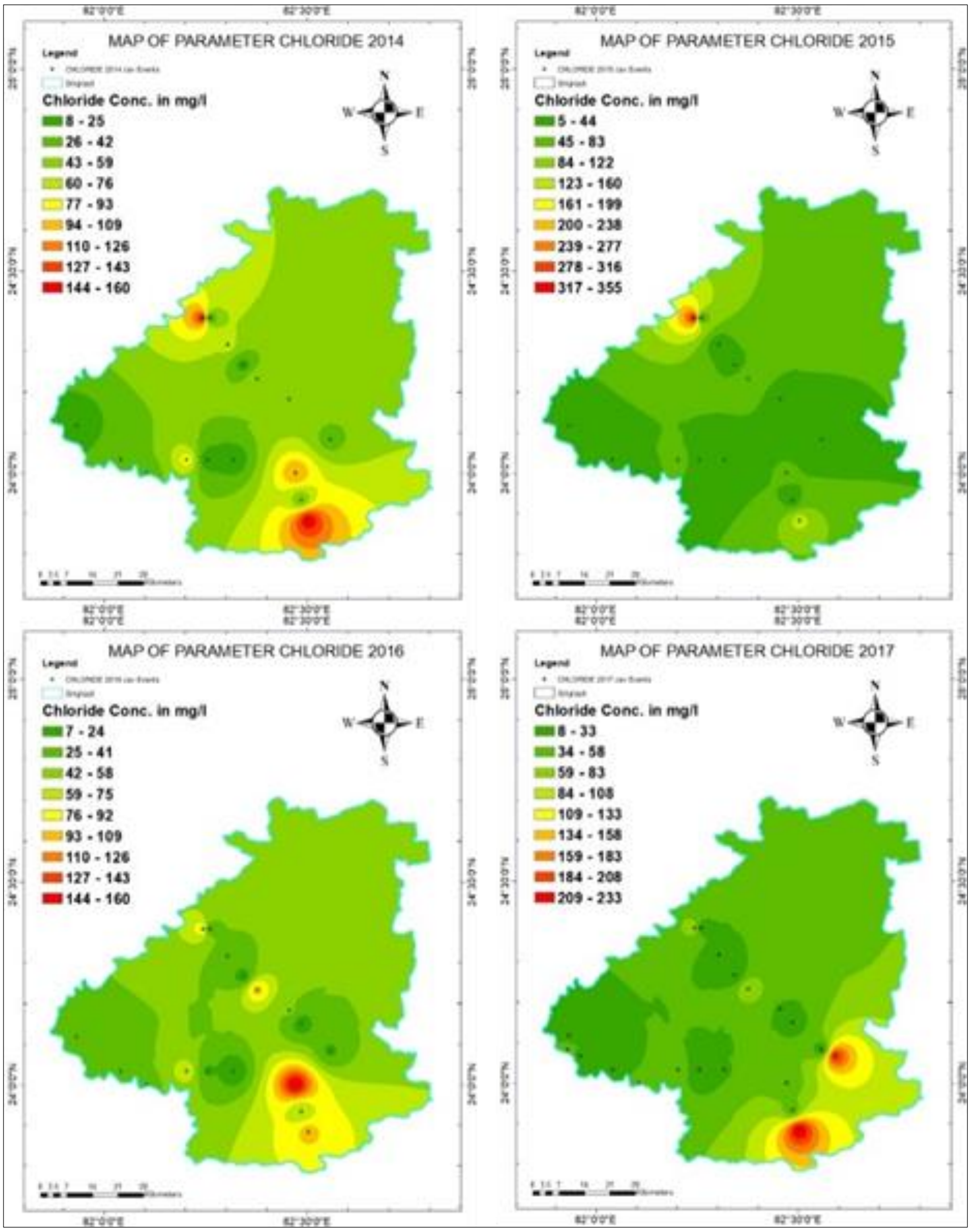


**Figure 5** Chloride distribution in the area of study over the period 2014-17

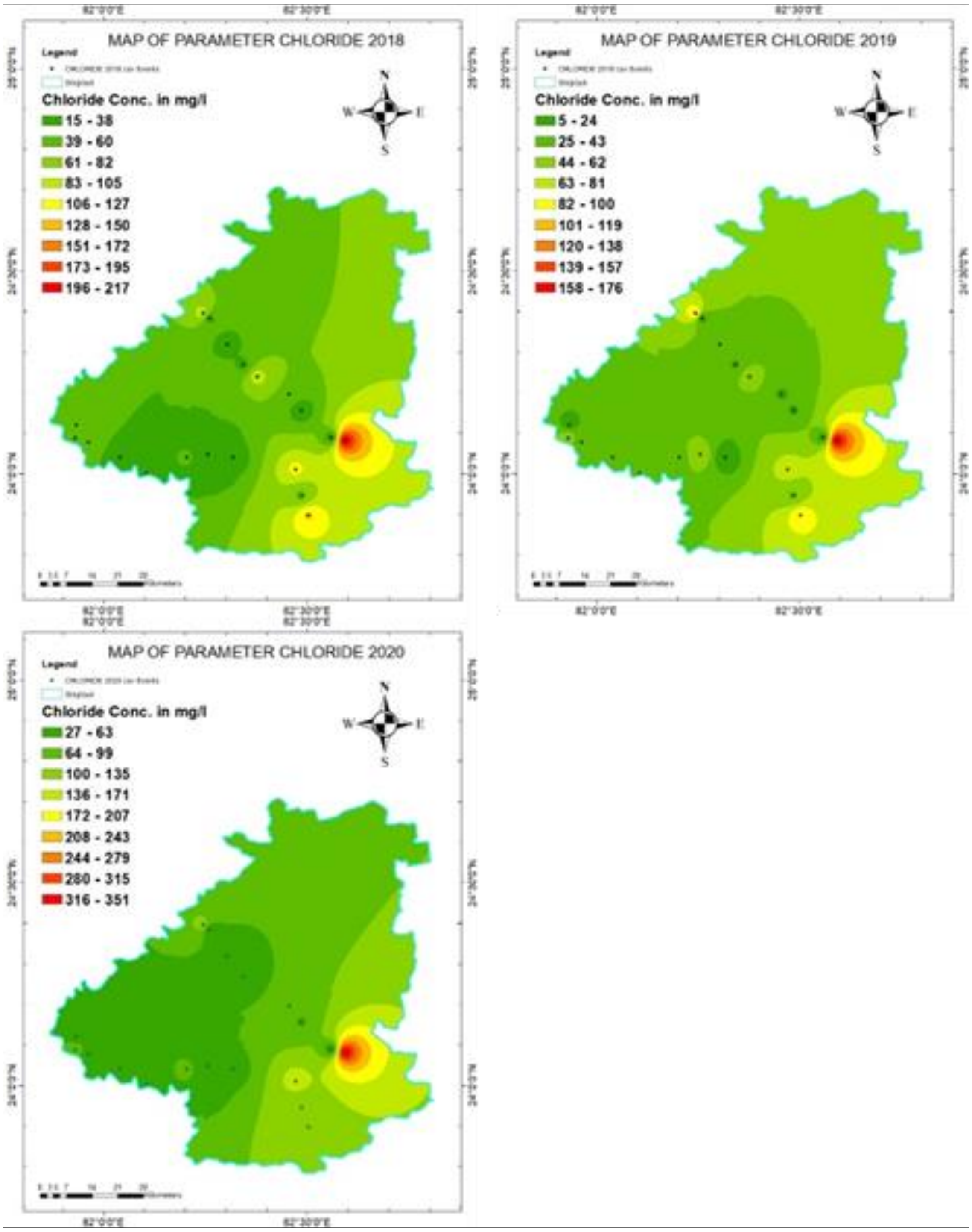


**Figure 6** Chloride distribution in the area of study over the period 2018-20

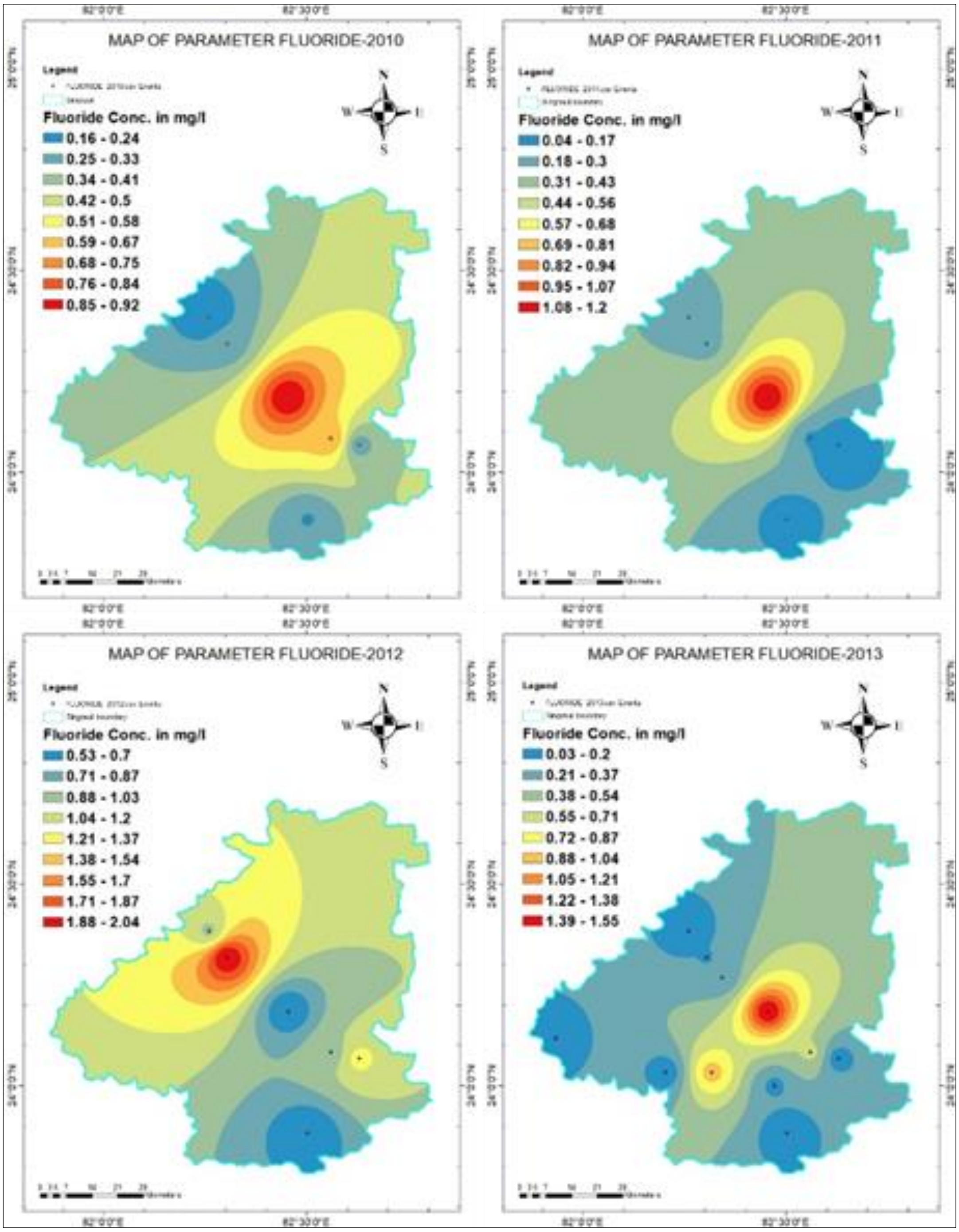


**Figure 7** Fluoride distribution in the area of study over the period 2010-13

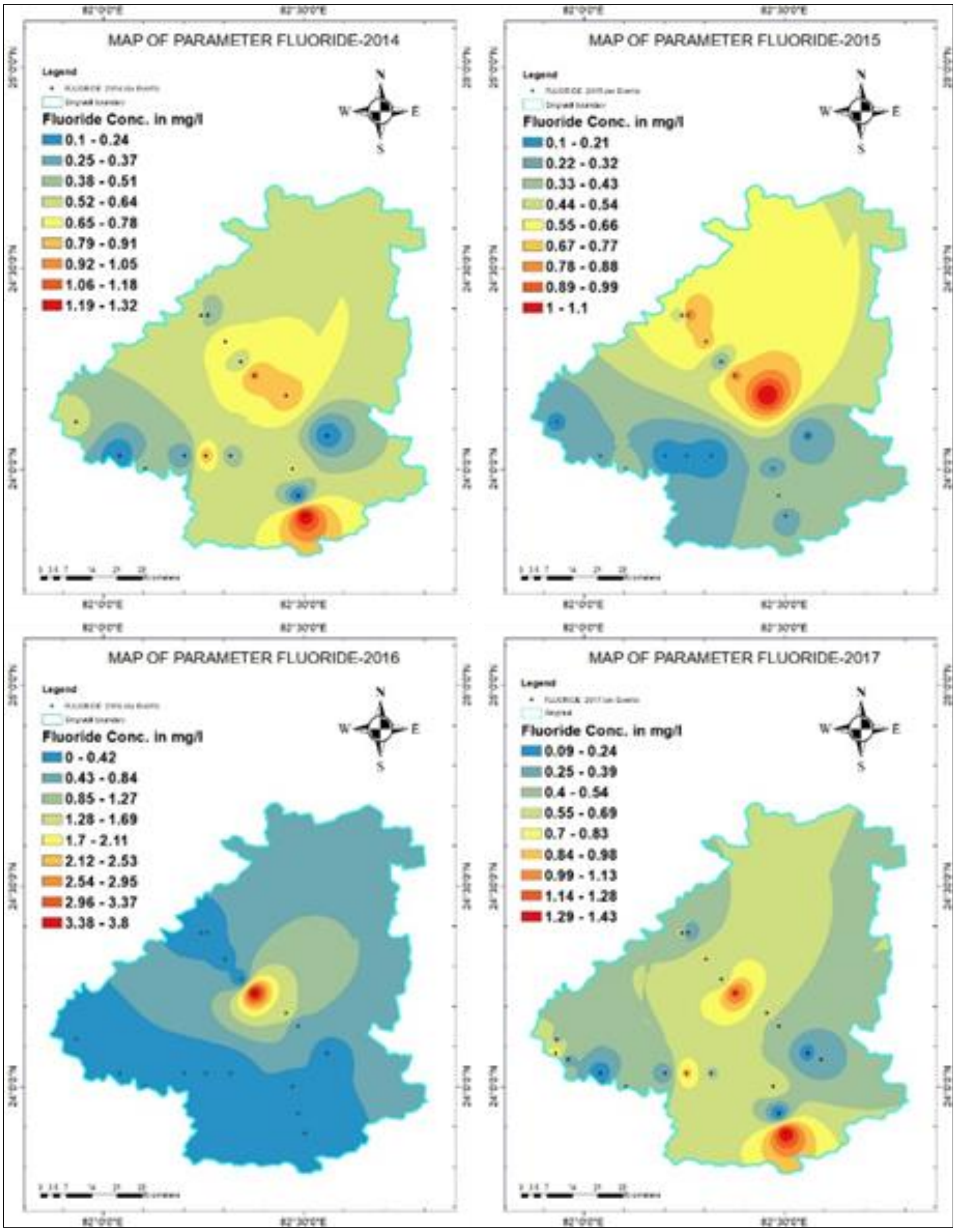


**Figure 8** Fluoride distribution in the area of study over the period 2014-17

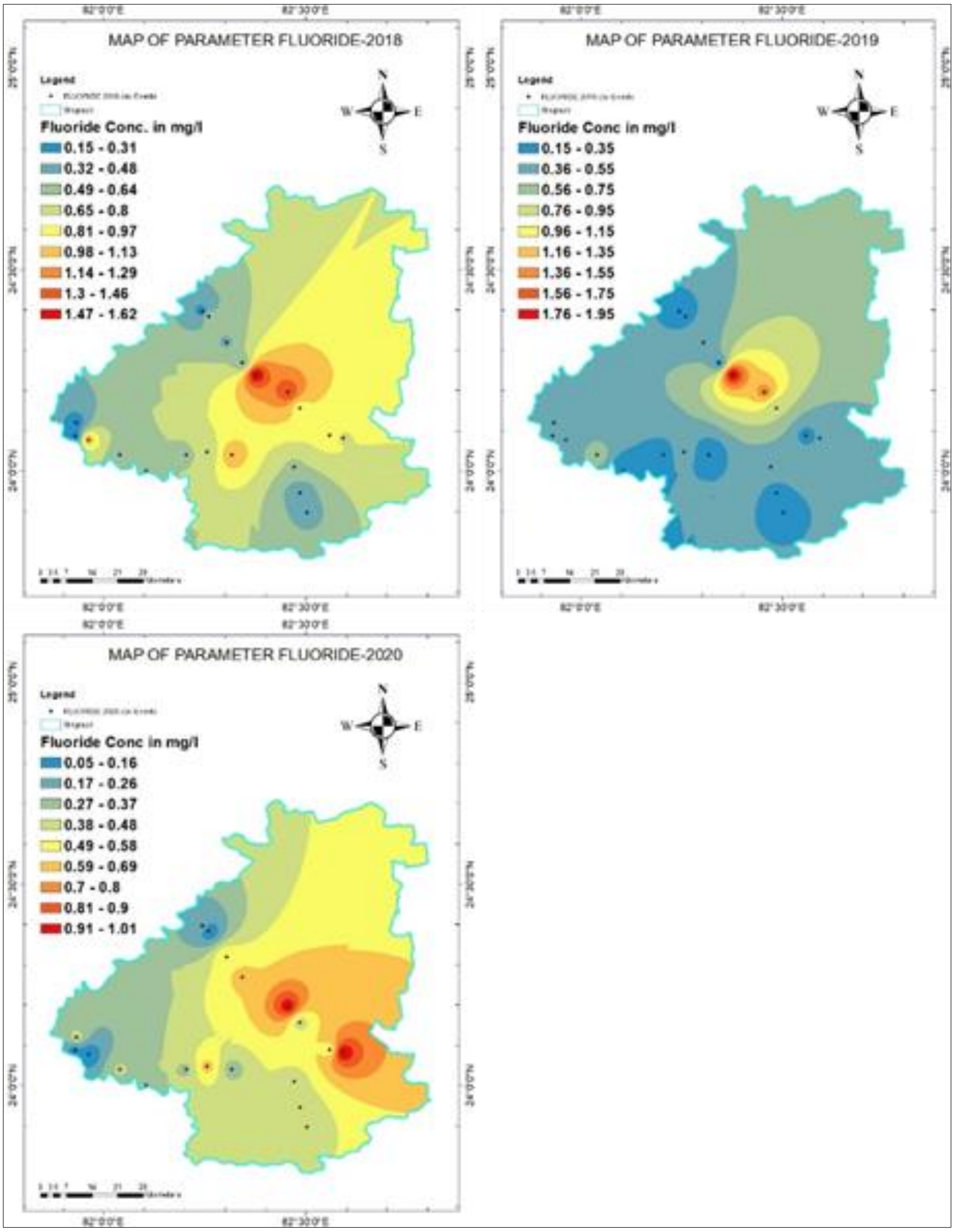


**Figure 9** Fluoride distribution in the area of study over the period 2018-20

## 4. Conclusion

Magnesium: The acceptable limit of Mg in drinking water is 30 milligram litre$^{-1}$ while permissible limit in the non presence of alternative water source is 100 milligram litre$^{-1}$ , as mentioned in Indian Standard for Drinking Water IS 10500: 2012 – specifications. The lowest average value of Mg in Singrauli's groundwater was 8.58 milligram litre$^{-1}$ for the year 2011. While the maximum average value of Mg concentration was 48.44 milligram litre$^{-1}$ for the year 2012. Also, the maximum value of Mg conc. in groundwater was 105.8 mg/l that was observed in the year 2012 at the location marked by coordinates 24.067,82.629 (Latitude, Longitude). All these values are within the permissible limit, that is 100 milligram litre$^{-1}$ except the max value that was observed at the location marked by the coordinates 24.067, 82.629 in the year 2012. So, we can conclude that groundwater quality is relatively safe as far as Mg concentration is concerned.

Chloride: According to Indian standard for drinking water, the acceptable limit of Chloride in drinking water is 250 milligram litre$^{-1}$ while permissible limit in the non-presence of alternative water source is 1000 milligram litre$^{-1}$. The lowest average value of Chloride in groundwater was 42.5 milligram litre$^{-1}$ in the year 2015. The highest average value of nitrate concentration over Singrauli region was 103.18 milligram litre$^{-1}$ for the year 2013 that was within the acceptable limit. The highest value of chloride conc. in groundwater was 355 mg/l at the location with Lat= 24.3833 and Long.= 82.243 which was within the permissible limit. At most places in the study area the conc. of chloride in the groundwater was found to be within the permissible limit.

Fluoride: According to Indian standard for drinking water, the acceptable limit of Fluoride in drinking water is 1 milligram litre$^{-1}$ while permissible limit in the non-presence of alternative water source is 1.5 milligram litre$^{-1}$. The lowest average value of Fluoride in groundwater was 0.33 milligram litre$^{-1}$ for the year 2011, while the maximum average value was observed to be 1.053 milligram litre$^{-1}$ for the year 2012. Maximum value of Fluoride conc. was 3.8 mg/l at the location marked by coordinates 24.233,82.377 (Lat., Long.) in the year 2016. The reason for this unusually high level of F conc. in the groundwater of Singrauli may be due to human activities like coal mining and leaching from the waste generated from the various power plants, etc.

## Compliance with ethical standards

### *Acknowledgments*

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### *Disclosure of conflict of interest*

The authors declare that they have no competing interests.

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