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(Research Article)

GIS-based change detection and assessment of groundwater quality in Agra, Uttar Pradesh

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Abstract

Groundwater is an essential and vital component of all life support systems. It is not only a basic need of human existence, but an essential contribution to all development activities. Groundwater quality in the Agra region is of particular importance and requires a lot of attention from all stakeholders. Because it is a major alternative resource for household, industrial, drinking and irrigation. The development of GIS based maps and change detection will help in evaluation of the risk at groundwater quality of Agra district, all the 14 blocks are considered for the evaluation with parameters pH, Electrical Conductivity (EC), Magnesium, Chloride & Calcium with which spatial maps are prepared from ArcGIS 10.8.2 software (2021). The further assessment was carried out with change detection for the years 2010 to 2024; with year 2010 as the base year the change detection maps are prepared with the help of ArcGIS Pro software (2023) the data for the same has been taken from the Central Groundwater Board (CGWB) and Groundwater Yearbook, Uttar Pradesh. It was found that the highest change values were in years 2014-2018, 2016-2018, 2013-2018, 2013-2014 & 2018-2023; for EC, Ca, Mg & Cl respectively in blocks like Akola, Jagner, Kheragarh and Achhnera. Differences in change values can be seen using plot graphs and maps. The limit standards prescribed for the parameters follow the Bureau of Indian Standards (BIS): IS 10500-2012 and World Health Organization (WHO) IS: 2011.

Keywords: Groundwater; Change Detection; Spatial Maps; ArcGIS Pro; CGWB; BIS

1. Introduction

Groundwater is an important component of life support systems. It is utilized for drinking, irrigation, and other industrial applications, among other things. However, groundwater resources are being depleted as a result of increasing population increase, urbanization, industrialisation, and agricultural activities. The intended usage of the water greatly influences its quality. As a result, the requirements for various reasons vary. Groundwater contamination has now become an environmental issue. A new generation's challenge [1]. Almost all living species require clean drinking water. Millions of human lives have already been lost. Waterborne sickness spreads swiftly as a result of undesired material elements washing into groundwater and inadequate sanitary settings. Groundwater contamination from a lack of cleanliness is increasing, as are illnesses associated with it; the United Nations (UN) considers access to clean water and sanitation to be a fundamental human right. [2]. Water quality criteria and standard techniques for reporting and comparing the findings of water quality analyses. Major chemical components such as pH, EC, Ca2+, Mg2+, Cl- play an important role in groundwater quality classification and assessment [3]. Geographic information systems (GIS) have evolved into an effective and strong tool in a variety of scientific domains over the last 20 years. GIS stores, organizes, searches, classifies, manipulates, analyses, and presents huge amounts of spatial data and information in an easy-to-understand manner [4]. GIS technologies reveal previously discovered geographical projections. It can be used for a variety of groundwater mapping applications. The evaluation of "spatial risk" in health sciences, geochemistry,

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pollution modelling, and climate GIS findings may provide useful information regarding high temperatures. Patch or risk distribution in limited geographic space for exploratory research.

When combined with other characteristics (for example, geochemical data, population data, etc.), spatial interpolation methods and GIS-based forecasting models provide useful visual data on regional scales concerning places and populations at risk [8]. With the help of the many methods offered, it is possible to identify changes in raster maps, satellite bands images, etc. over time, cumulatively, or for an entire year. The changes that occur could be of the categorical, time series, or pixel variety.

The current paper's goal is to examine the groundwater quality in fourteen different Agra district, Uttar Pradesh, India, blocks: Achhnera, Akola, Bichpuri, Barauli Ahir, Barhan, Etmadpur, Fatehabad, Fatehpur Sikri, Jagner, Jaitpur Kalan, Khandauli, Kheragarh, Pinahat, Saiyan and Shamshabad, with a focus on pH, EC, Mg, Cl and Ca distribution and contamination. The permissible limits are considered according to WHO: 2004 [9] and IS: 10500:2012 [10].

2. Material and Methods

2.1. Study Area

Agra district covers approximately 4027 km^2 [11] and is located between 26°45' to 27°30′ N latitudes and 77°30′ to 78°30′E longitude (Figure 1) at heights between 150 and 200 meters above mean sea level. According to the Directorate of Census Operations, Uttar Pradesh [12] the official census 2011 for the Agra district, the total population of the district was 4,418,797 lakhs. The Yamuna River separates the study area into two sections: Trans-Yamuna and Cis-Yamuna, which occupy the city's northern and southern halves, respectively. The Agra urban region is a part of the Central Ganga Plains, which has a fluvial terrigenous clastic depositional system made of ancient and newer Quaternary alluvial materials. The newest alluvium is found in the busy flood plains of the Yamuna River in the lowlands and is made up of micaceous greyish sands, silt, and clay. More mature alluvium on highlands is made of unconsolidated sediments from alluvium consisting of inter layered 1-2 meters thick fine sand and silty mud layers with patches of upper to middle pleistocene 'kankar or calcrete' horizons (concretionary type impure carbonate). Kankar occur as discontinuous patches on the higher plateau surface and have large 0.5-1.0 m thick strata in the top few meters of the central alluvial plain [13].

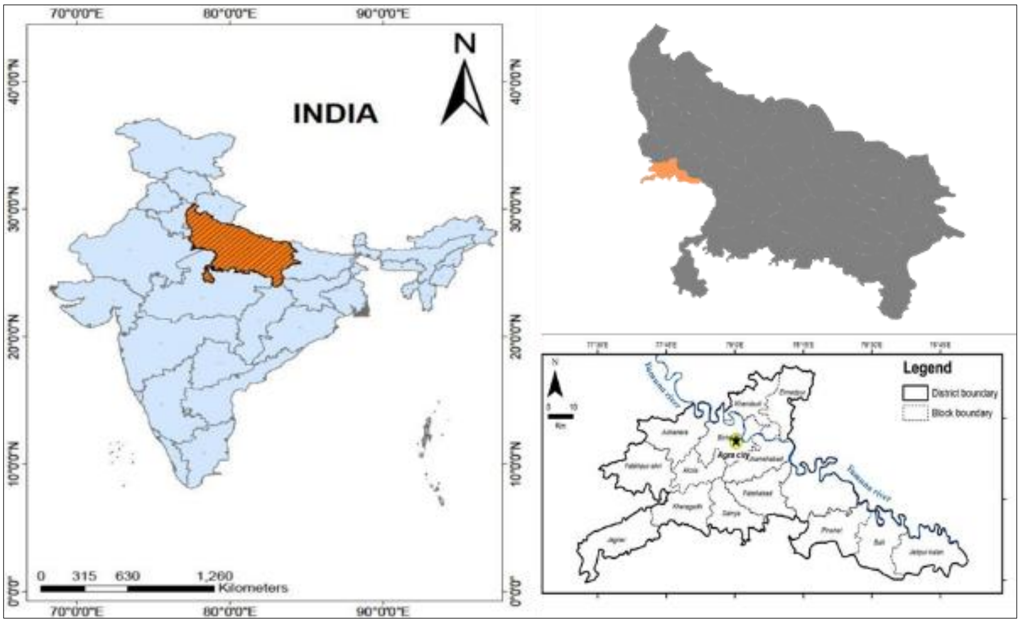


Figure 1 Locational map of study area Agra

2.2. Data Collection and Parameters

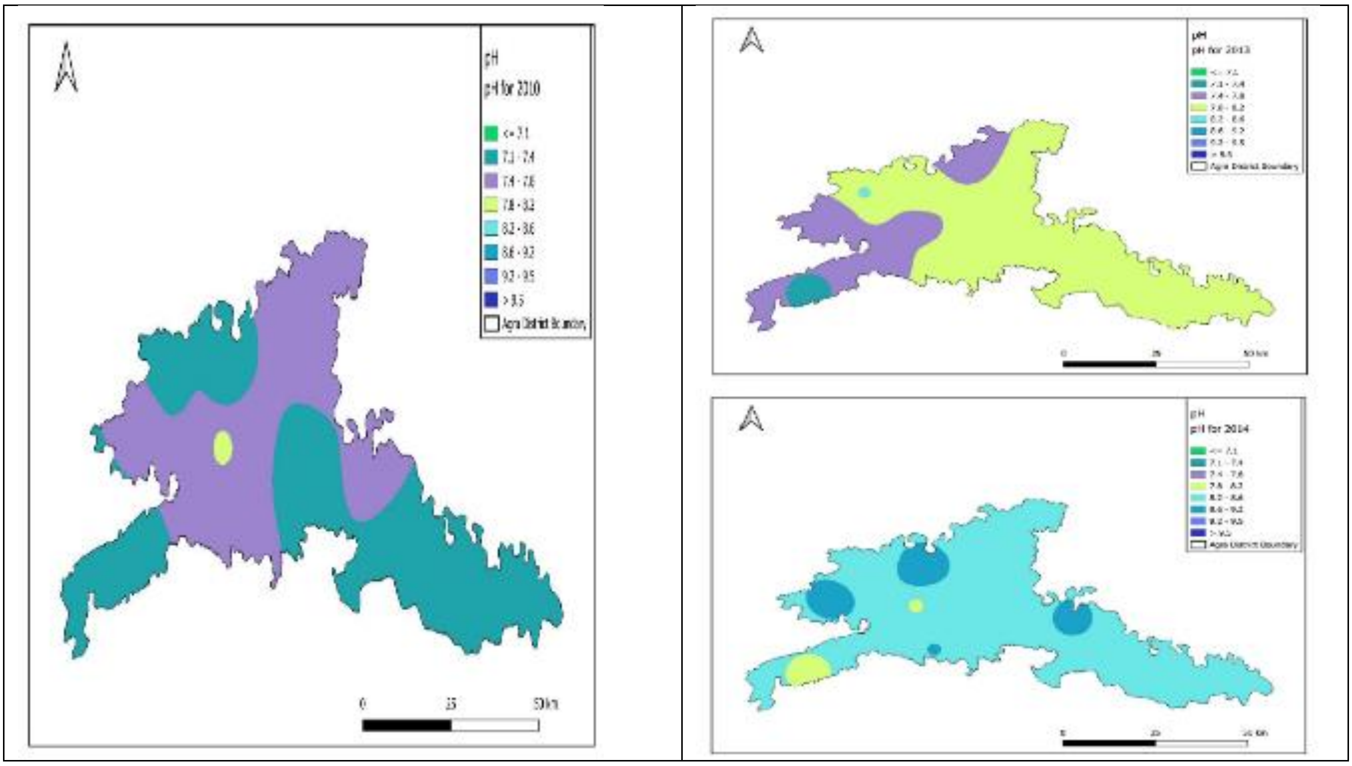
Almost data for the considered parameters i.e.; pH, Electrical Conductivity (EC), Magnesium, Chloride & Calcium are taken for the year 2010 to 2023 from the Central Groundwater Board (CGWB) [14]. The data of groundwater quality of year 2024 are taken from the Groundwater Yearbook, Uttar Pradesh [15]. A complete 15 years of data for the selected

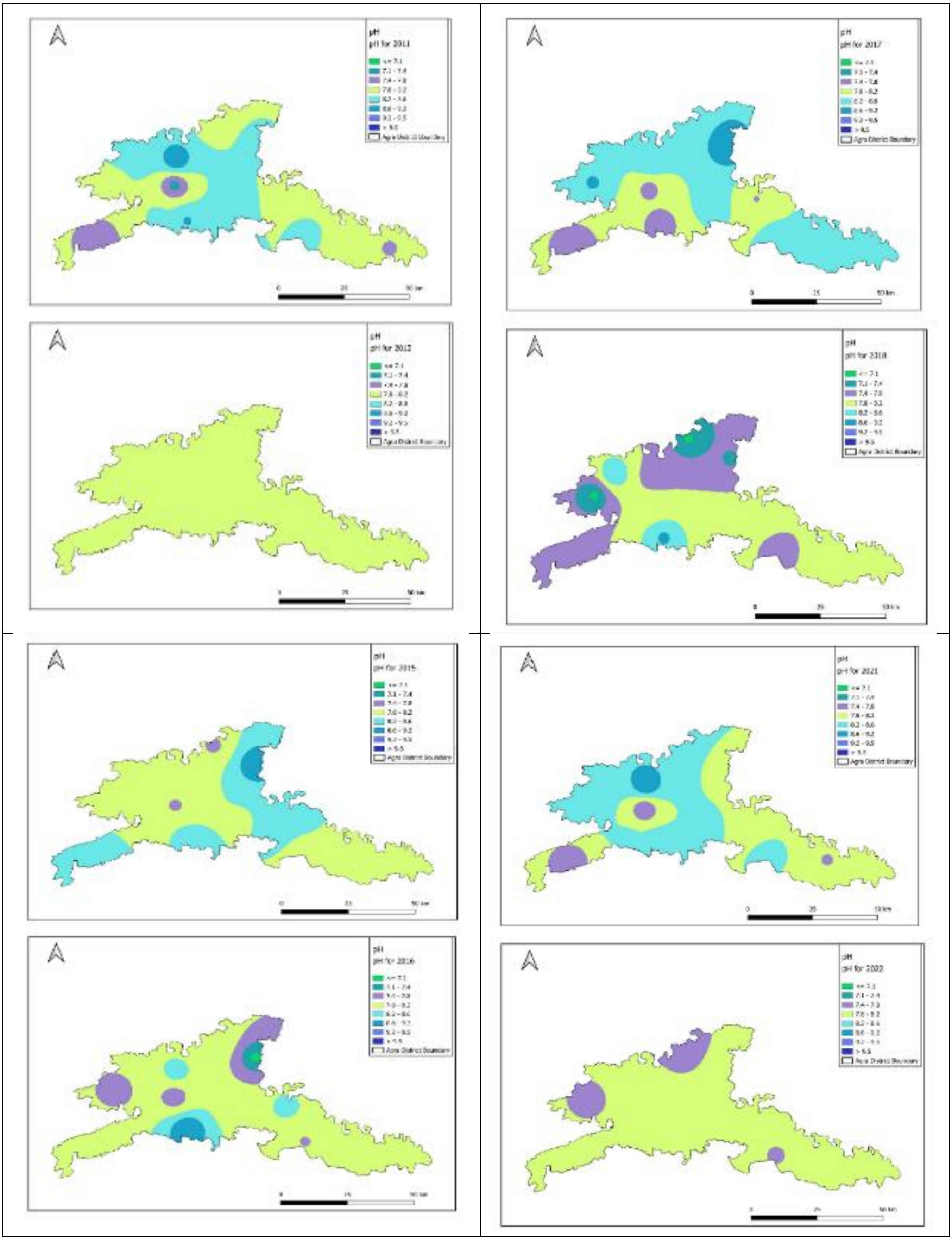
5 parameters for district Agra is considered. The location marked on maps are according to the year books for 14 blocks of Agra district which are Achhnera, Akola, Bichpuri, Barauli Ahir, Barhan, Etmadpur, Fatehabad, Fatehpur Sikri, Jagner, Jaitpur Kalan, Khandauli, Kheragarh, Pinahat, Saiyan and Shamshabad (Figure 2). The data for the change detection analysis will be taken from the raster maps/band which are prepared using Arc GIS Pro (2023).

2.3. Visualization and Analysis

2.3.1. GIS Based Spatial Mapping

GIS can serve as a powerful tool for water quality modelling. Using GIS, you can create various thematic maps to help understand and manage water resources. In this study, spatial maps with the method interpolation using IDW (Inverse Distance-Weighted) GIS approach is used. In this method, the grid output values are estimated by selecting sample points at different locations. A surface mesh is created with thematic contours, as it uses a linearly weighted combination of sample points to determine cell values and controls the importance of known points in the interpolated values based on their distance from the output point. The analysis of area is done through 3D analyst tool in hectares so that the area of each site is determined, which helps in the calculation of area of each site, here in hectare with the geometry calculator. Furthermore, to change the polygon into raster the conversion tool is used, the range of the prepared maps is determined with the help of GIS when the polygon changes into raster dataset. The maps are prepared with the projection of UTM-WGS-1984-Northern Hemisphere-44N with geographic projection of World-WGS-1984; for parameters pH, EC, Mg, Cl and Ca in Figures 2-6 respectively.




pH
pH for 2011
pH
pH for 2017
pH
pH for 2012
pH
pH for 2018
pH
pH for 2015
pH
pH for 2021
pH
pH for 2016
pH
pH for 2022

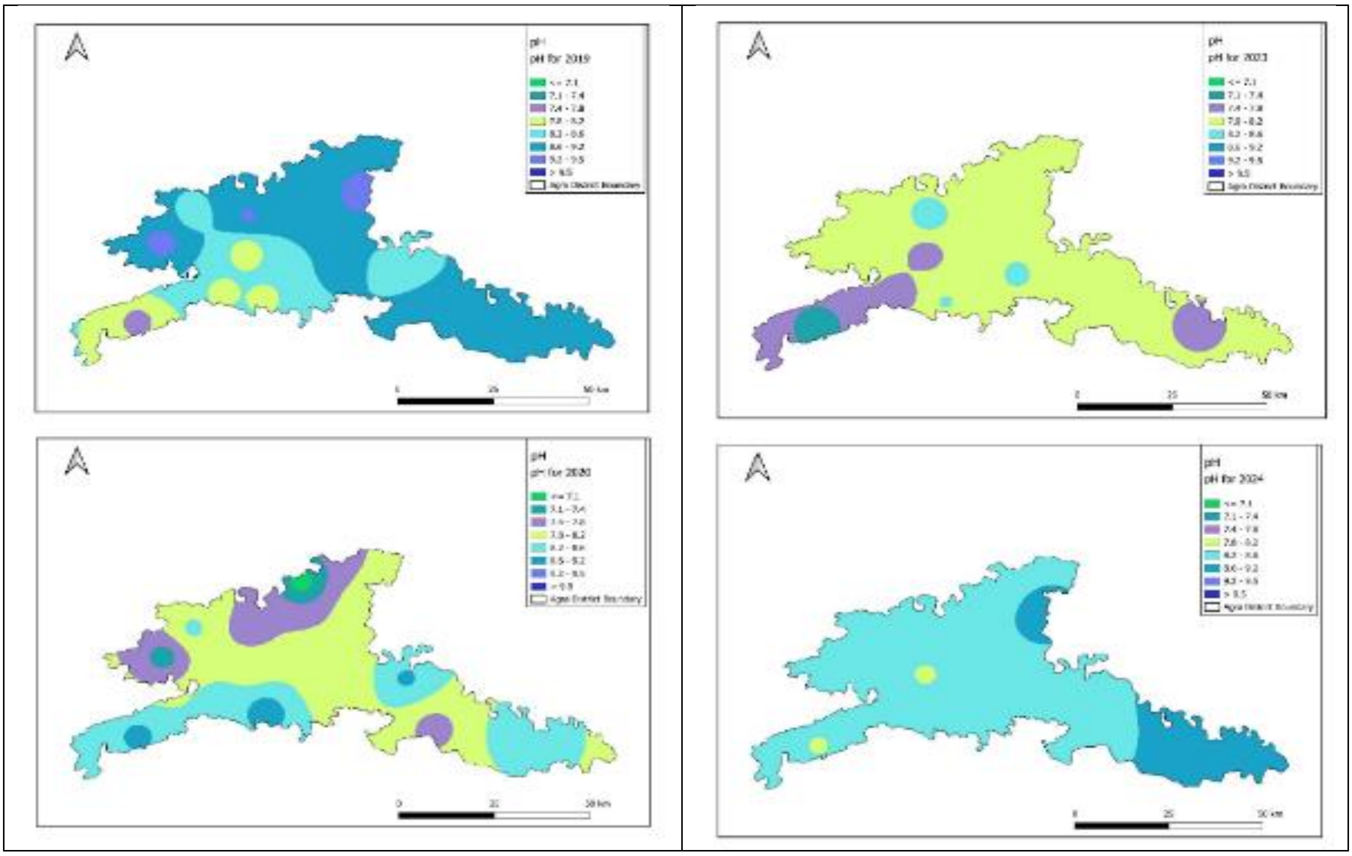
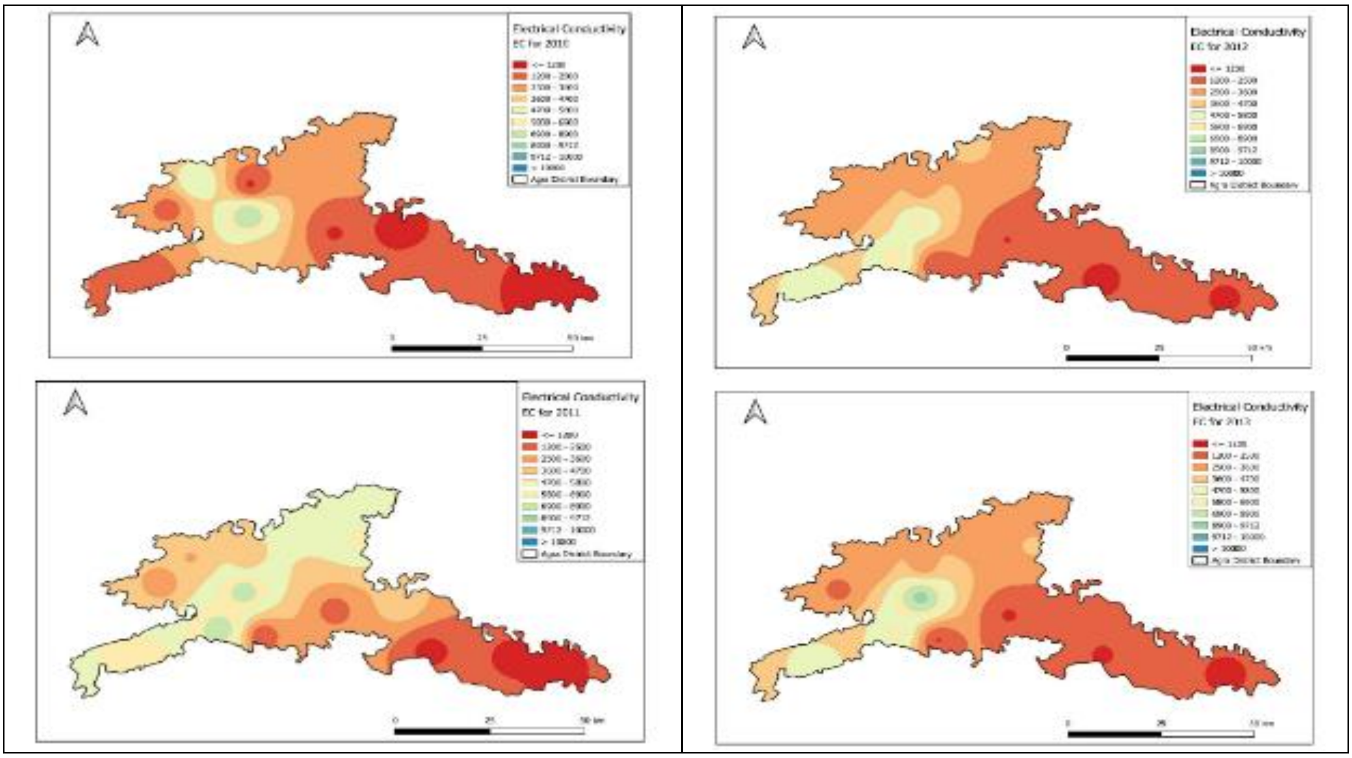
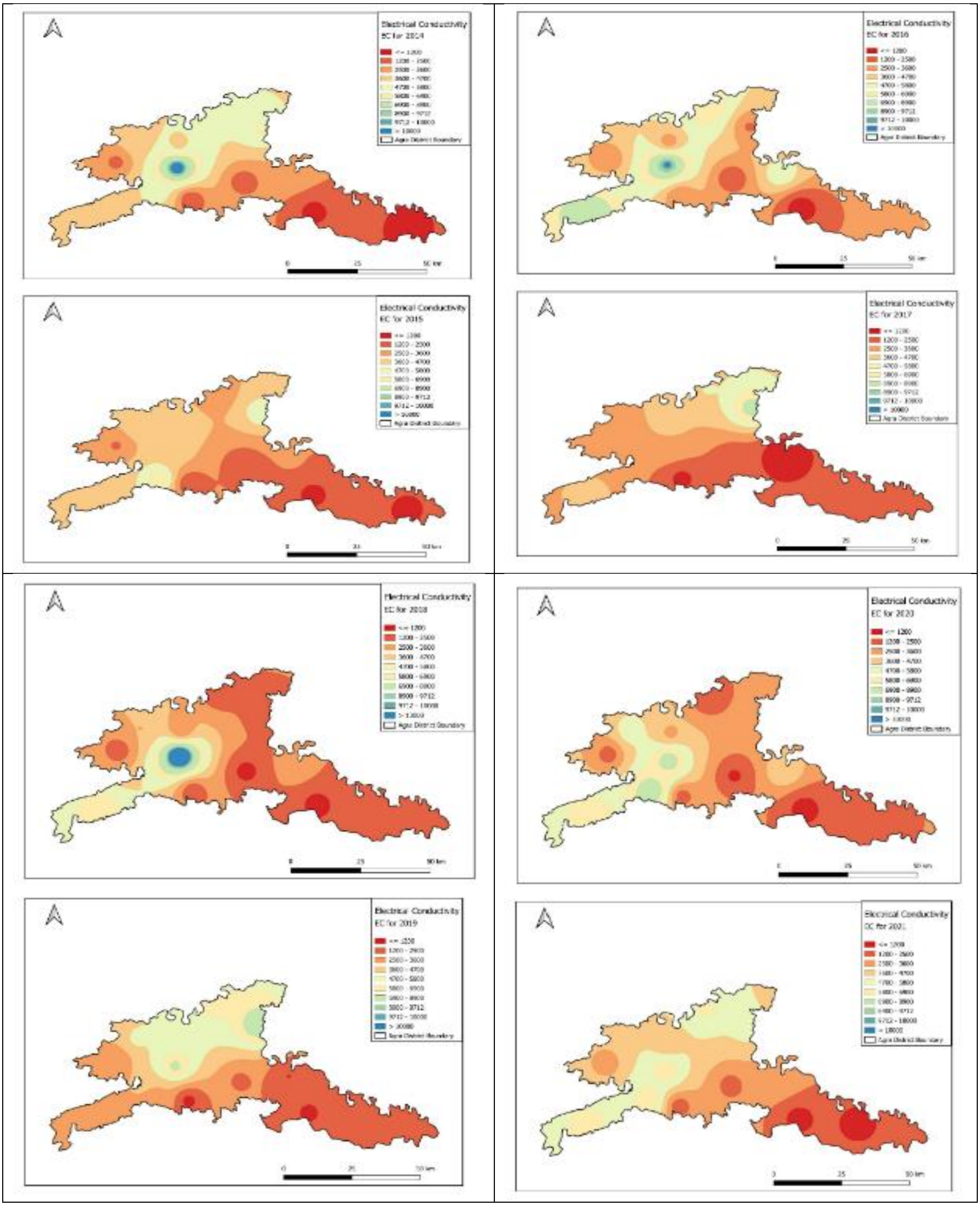


Figure 2 Spatial Maps of Parameter pH (Years 2010 to 2024)




Electrical Conductivity
EC for 2014
Electrical Conductivity
EC for 2016
Electrical Conductivity
EC for 2015
Electrical Conductivity
EC for 2017
Electrical Conductivity
EC for 2018
Electrical Conductivity
EC for 2020
Electrical Conductivity
EC for 2019
Electrical Conductivity
EC for 2021
0 25 50 km

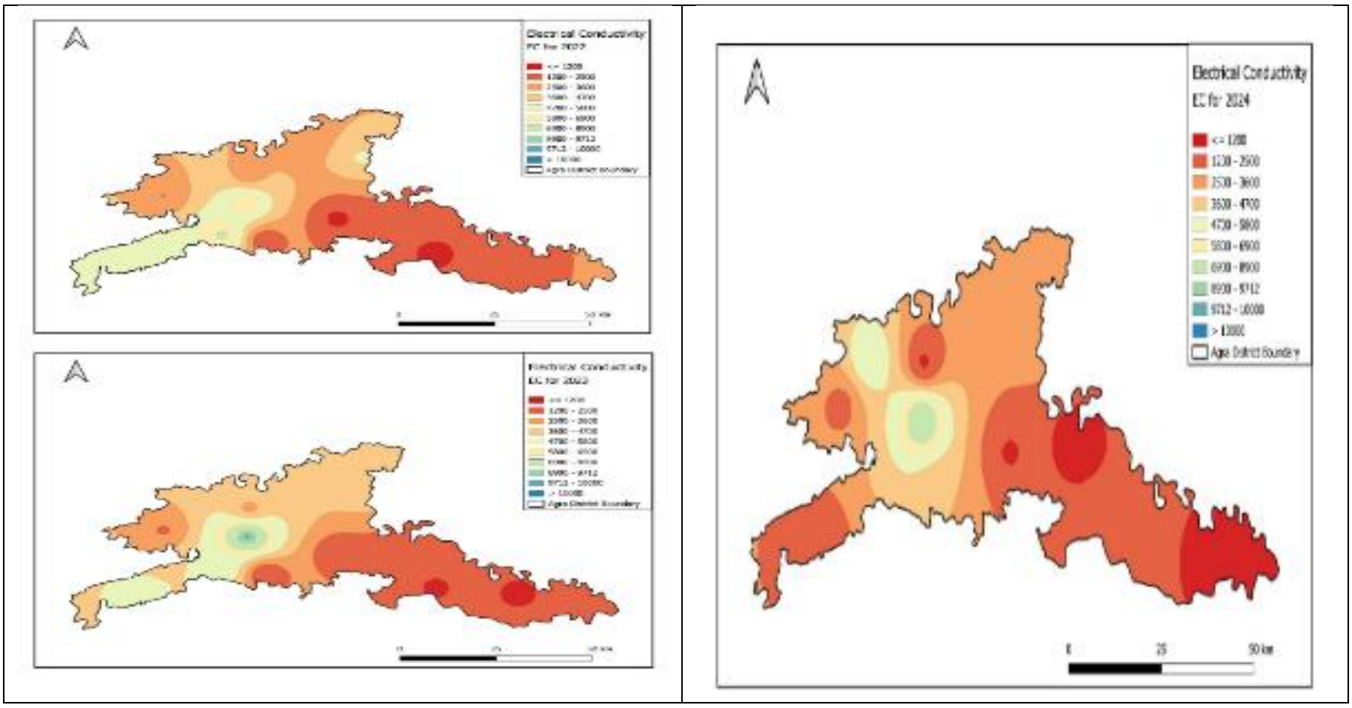
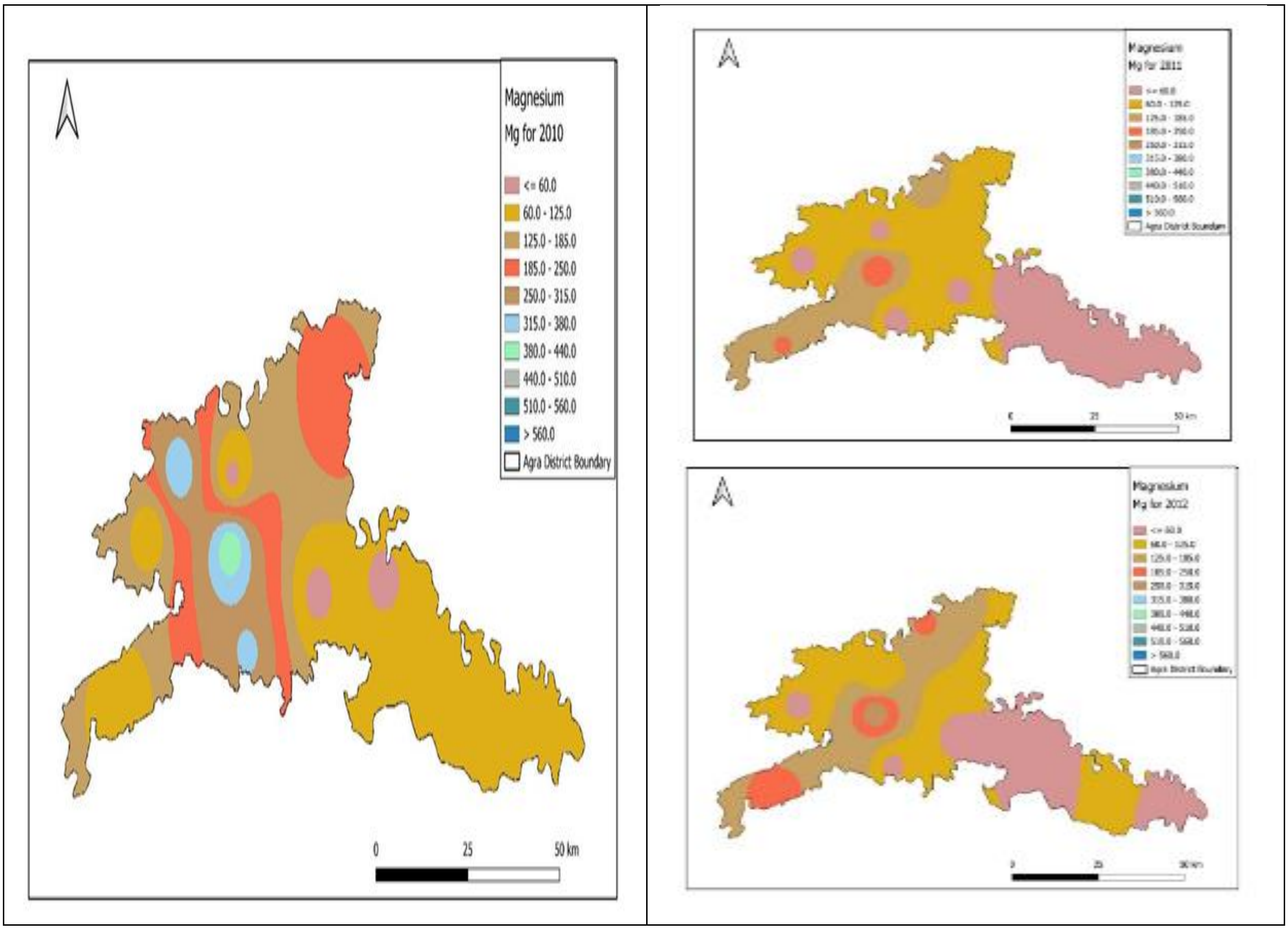
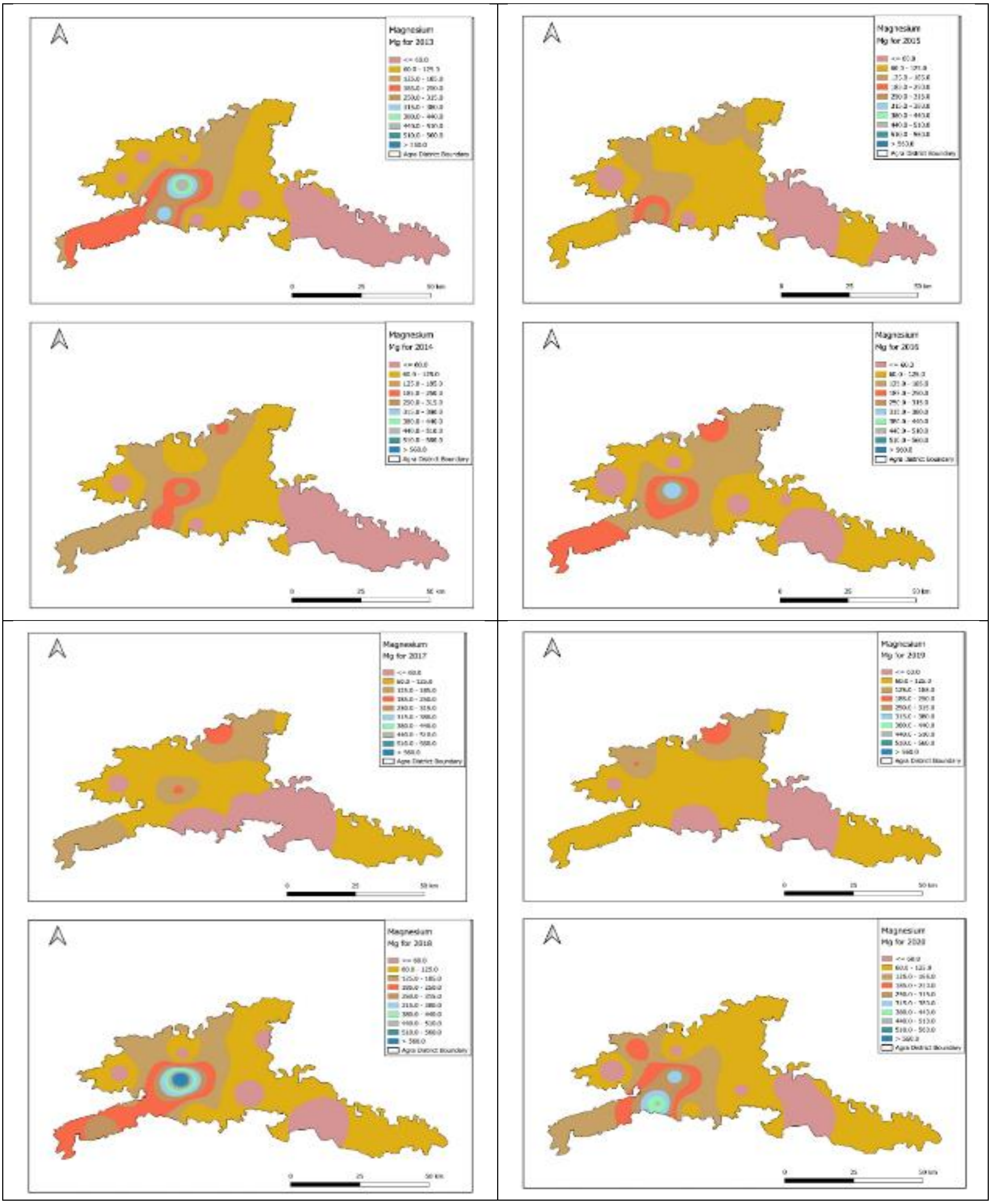


Figure 3 Spatial Maps of parameter EC (Years 2010 to 2024)




Magnesium
Mg for 2013
Magnesium
Mg for 2015
Magnesium
Mg for 2014
Magnesium
Mg for 2016
Magnesium
Mg for 2017
Magnesium
Mg for 2019
Magnesium
Mg for 2018
Magnesium
Mg for 2020

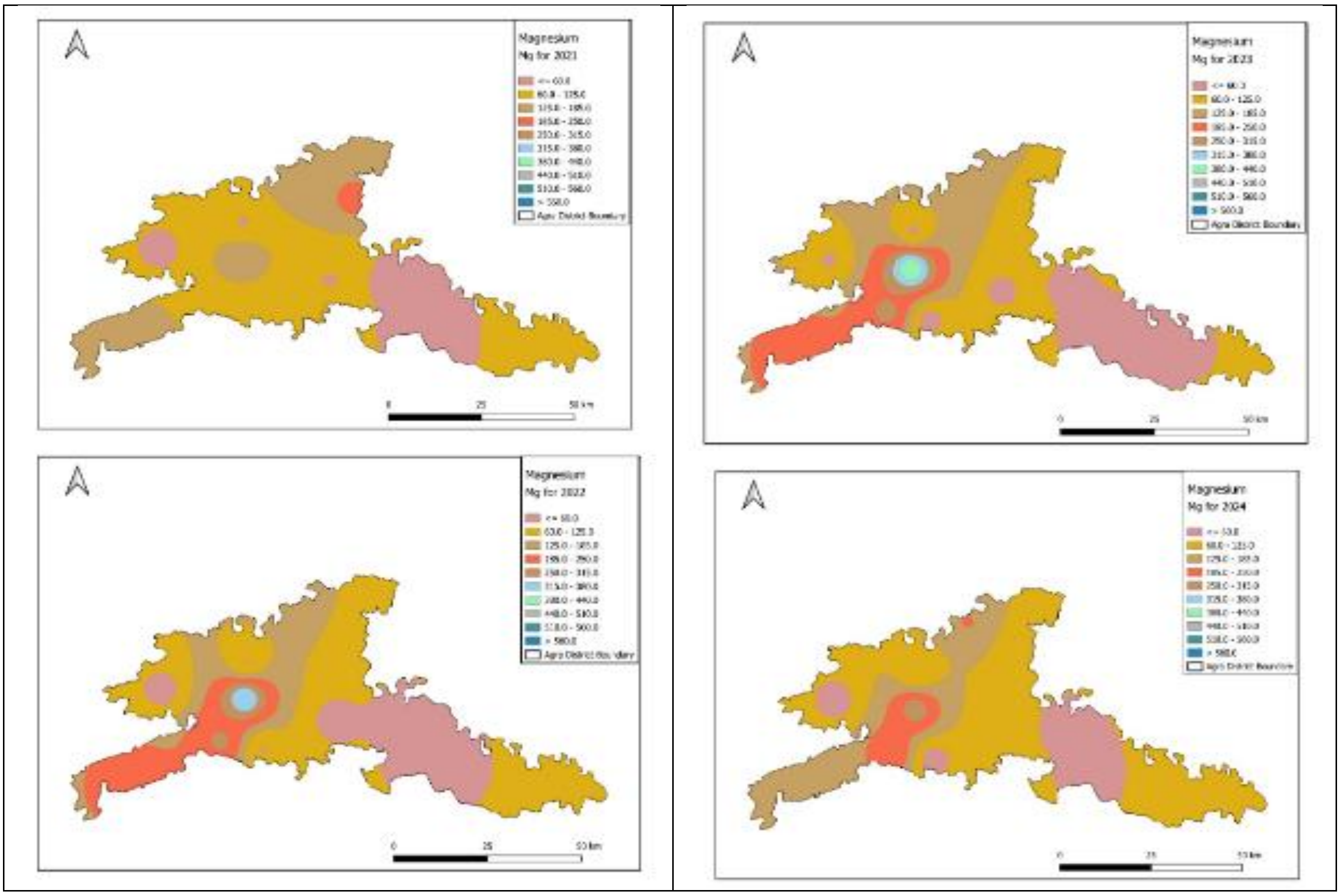
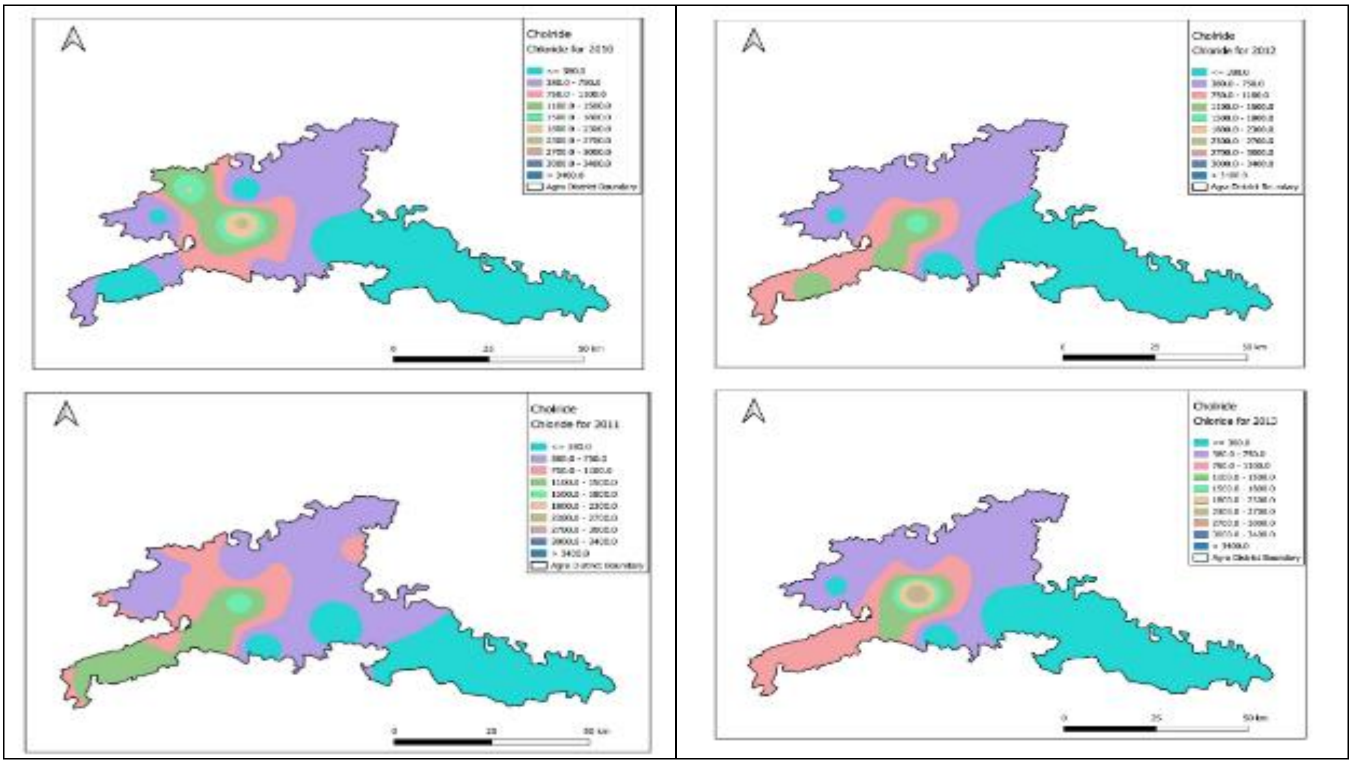
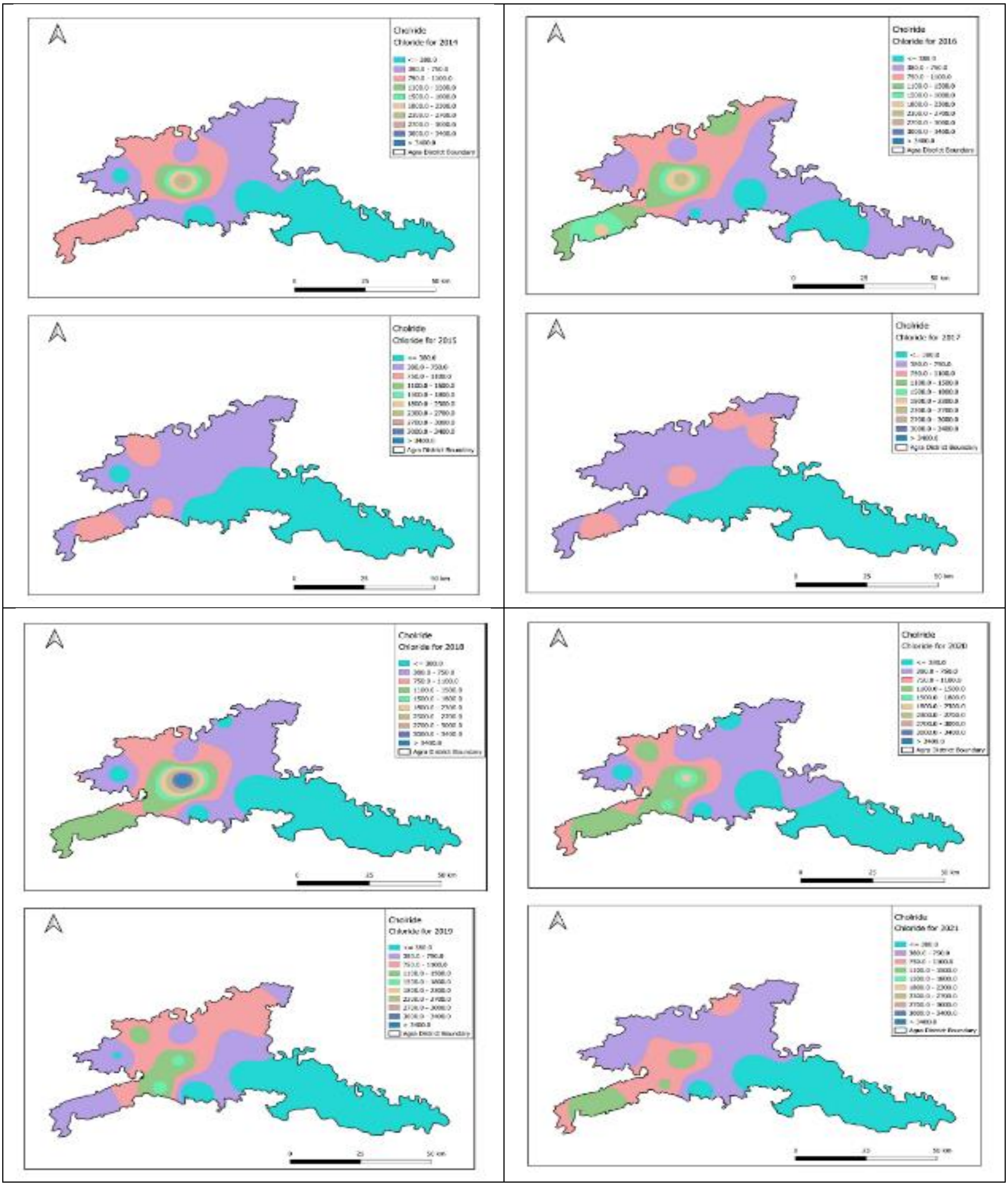


Figure 4 Spatial Maps of Parameter Magnesium (Mg2+) (Years 2010 to 2024)




Chloride for 2014
Chloride for 2016
Chloride for 2015
Chloride for 2017
Chloride for 2018
Chloride for 2020
Chloride for 2019
Chloride for 2021

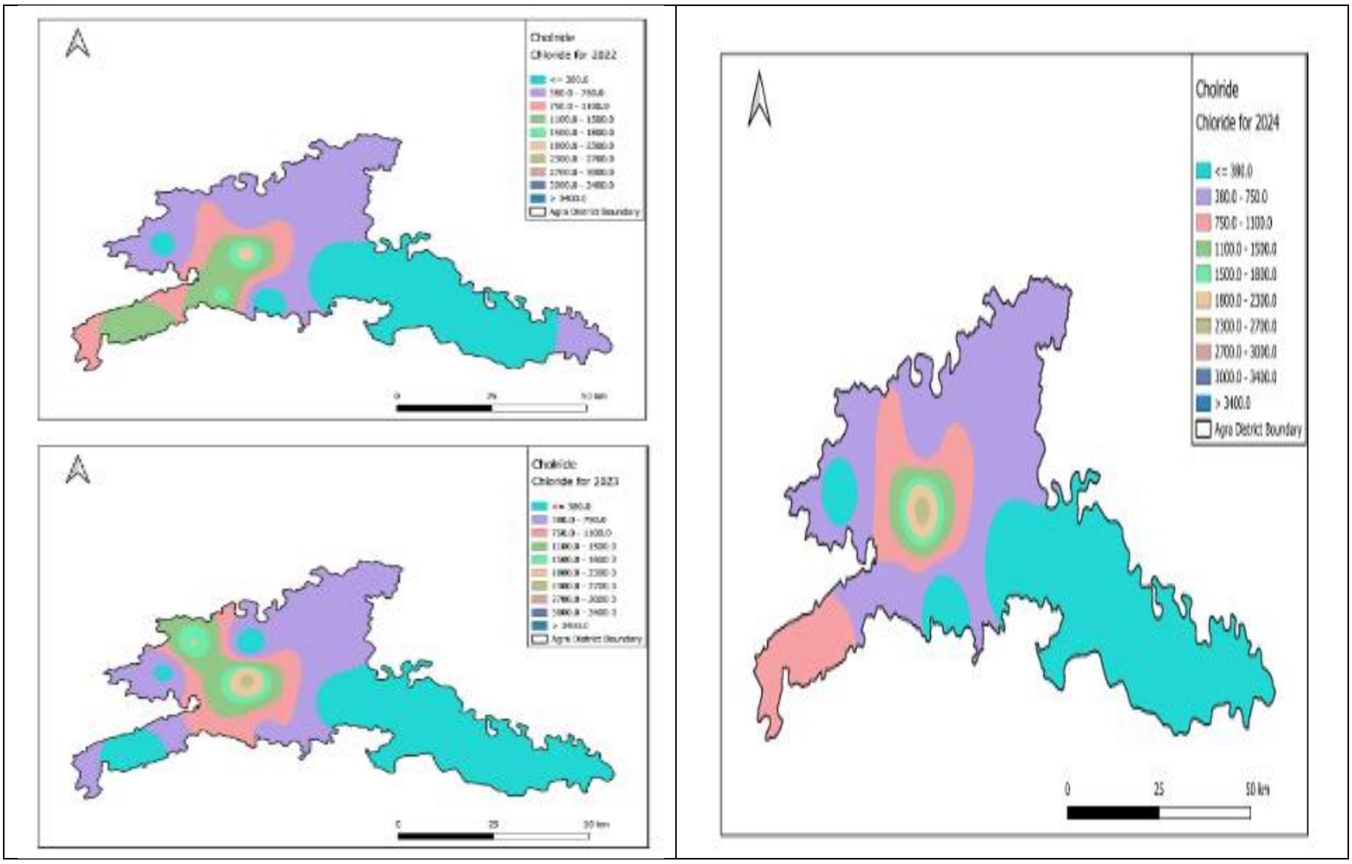
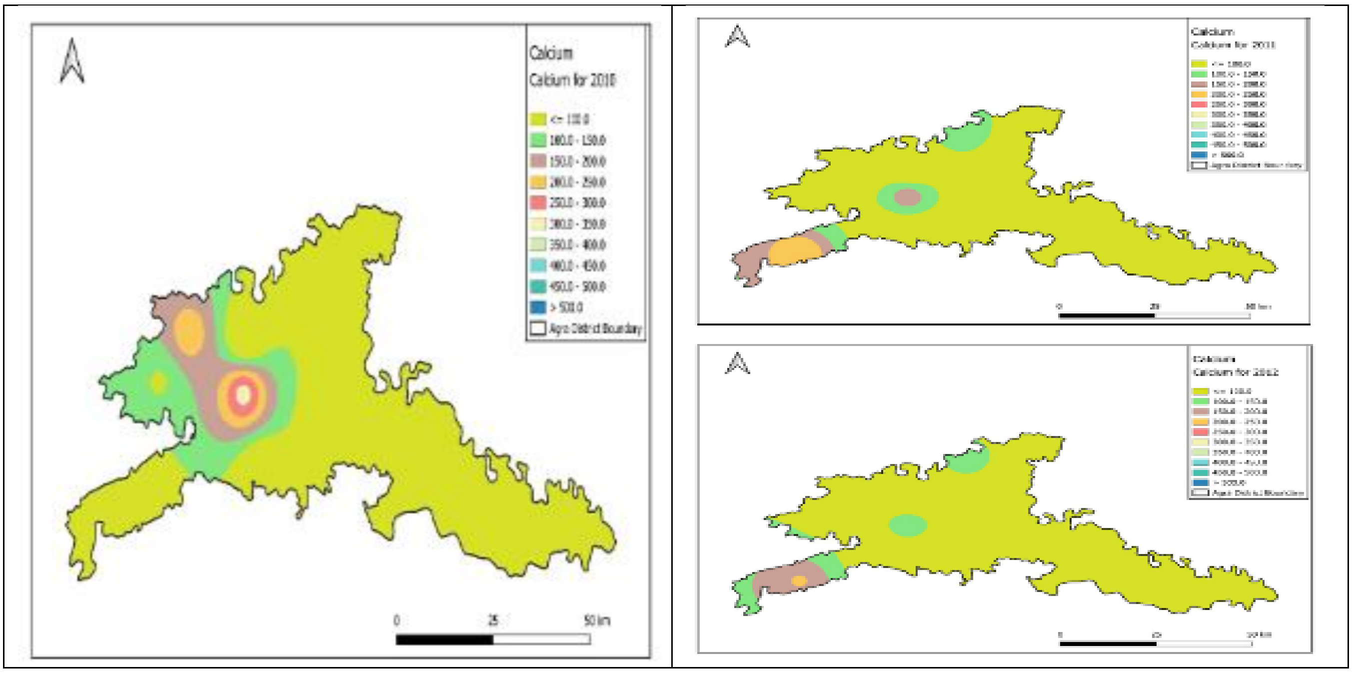
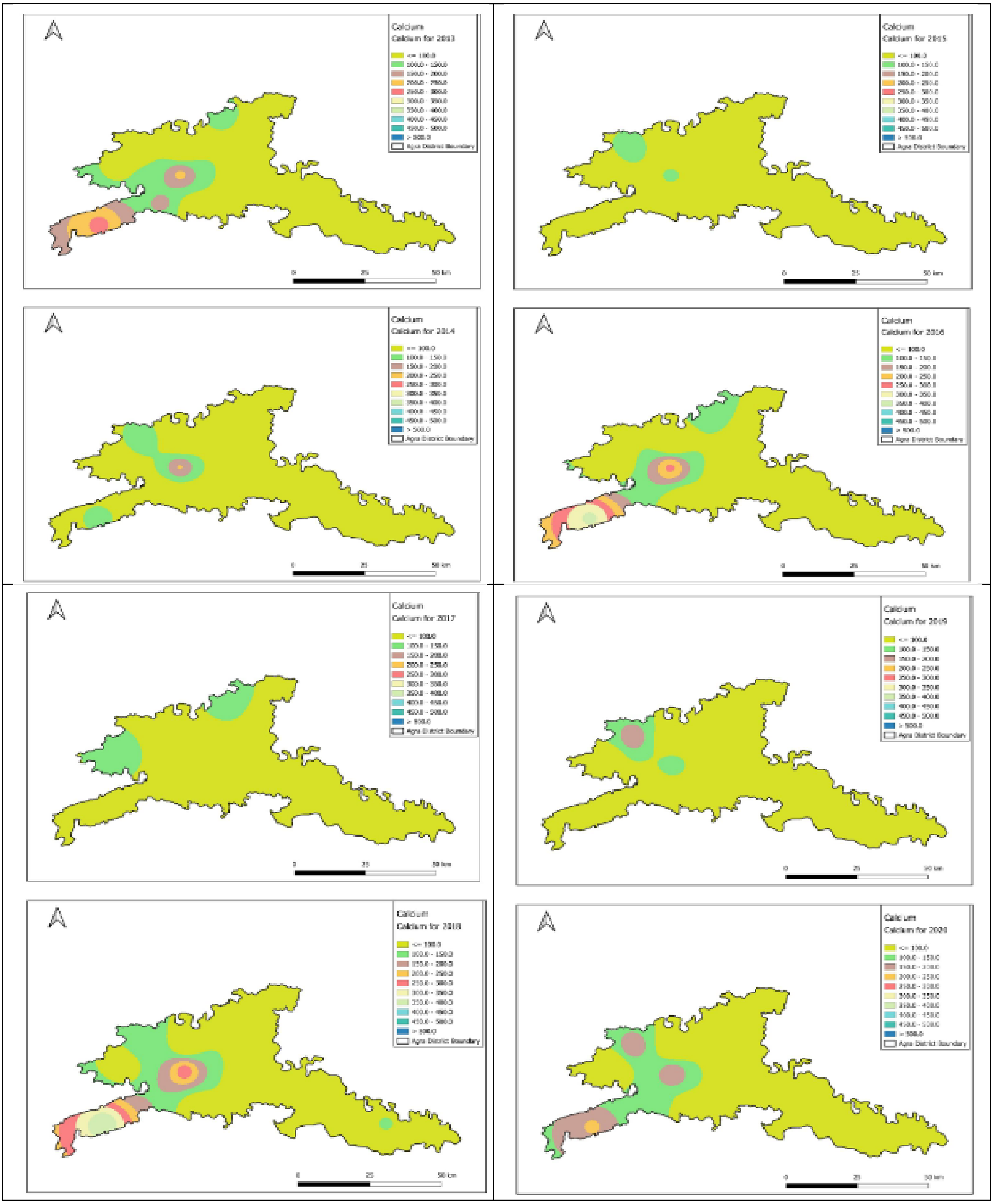


Figure 5 Spatial Maps of Parameter Chloride (Cl-) (Years 2010 to 2024)




Calcium
Calcium for 2013
Calcium
Calcium for 2015
Calcium
Calcium for 2014
Calcium
Calcium for 2016
Calcium
Calcium for 2017
Calcium
Calcium for 2019
Calcium
Calcium for 2018
Calcium
Calcium for 2020

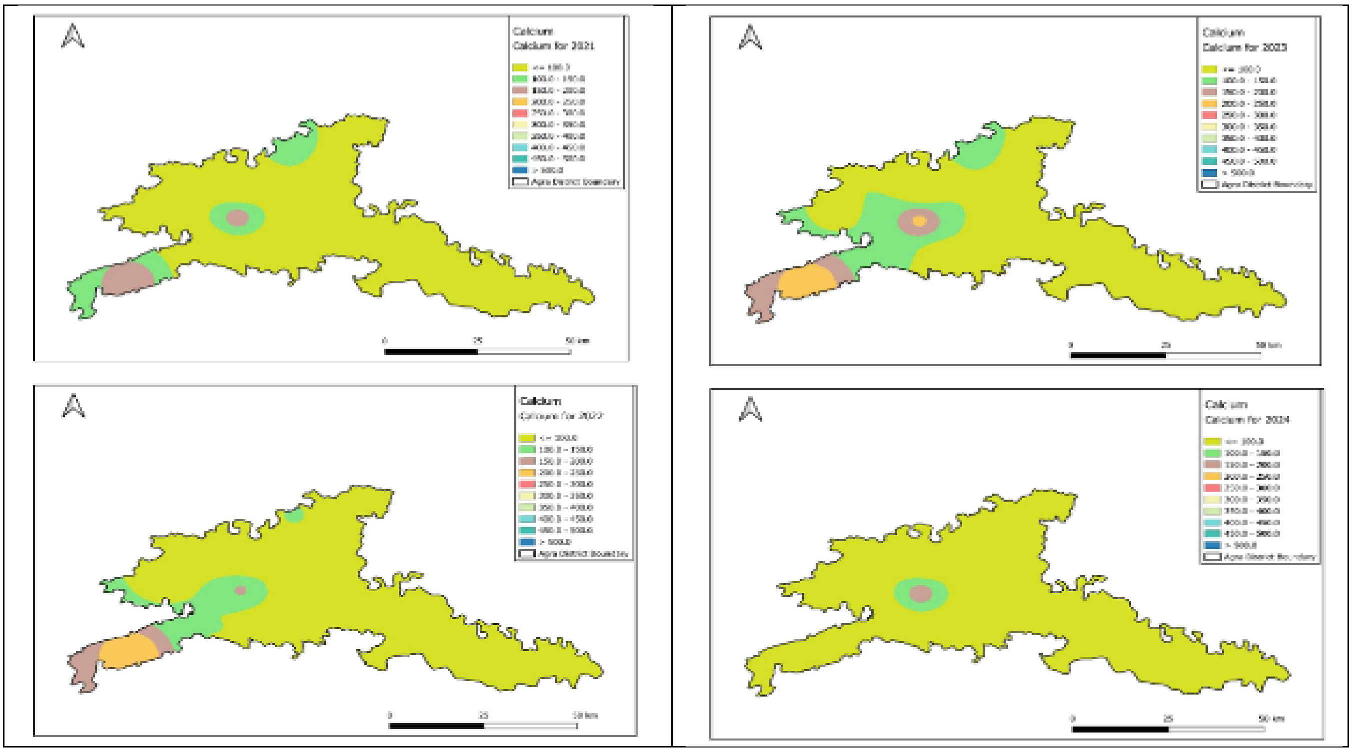


Figure 6 Spatial Maps of Parameter Calcium (Ca2+) (Years 2010 to 2024)

2.3.2. GIS Based Change Detection

The change detection is done through the method pixel value change detection, the purpose of comparing modelled data is typically to identify areas that have changed in magnitude or in a particular direction, usually over a period. The two raster bands are (here the base year taken is 2010 in correspondence to the cumulative maps till the year 2024 are prepared simultaneously) extracted to compute changes [16]. The difference type here was absolute with single band difference method with the intersection of extent type; the change detection is made for parameters pH, EC, Mg, Cl and Ca which are illustrated in Figures 7-11 respectively.

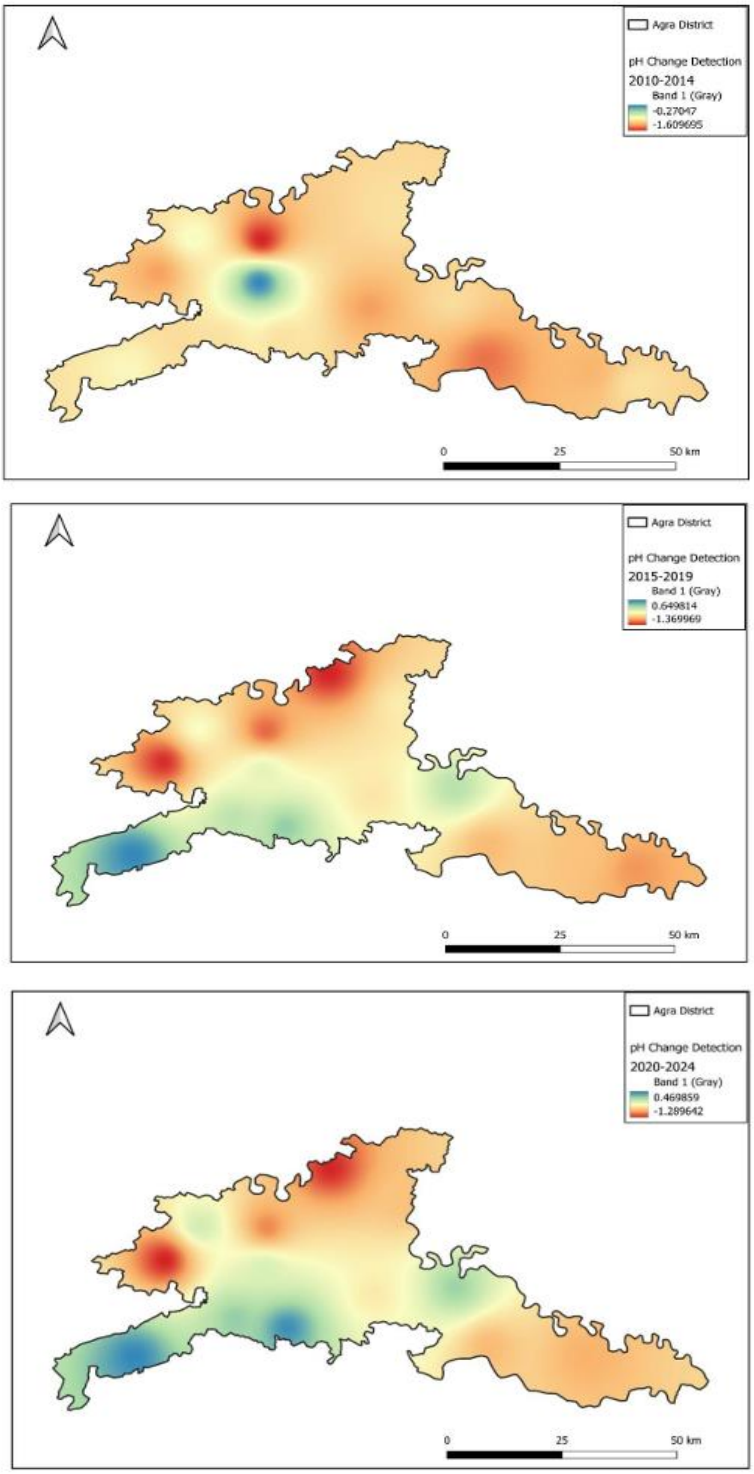


Figure 7 Change Detection of parameter pH (for year 2010 to 2014, 2015-2019 & 2020-2024)

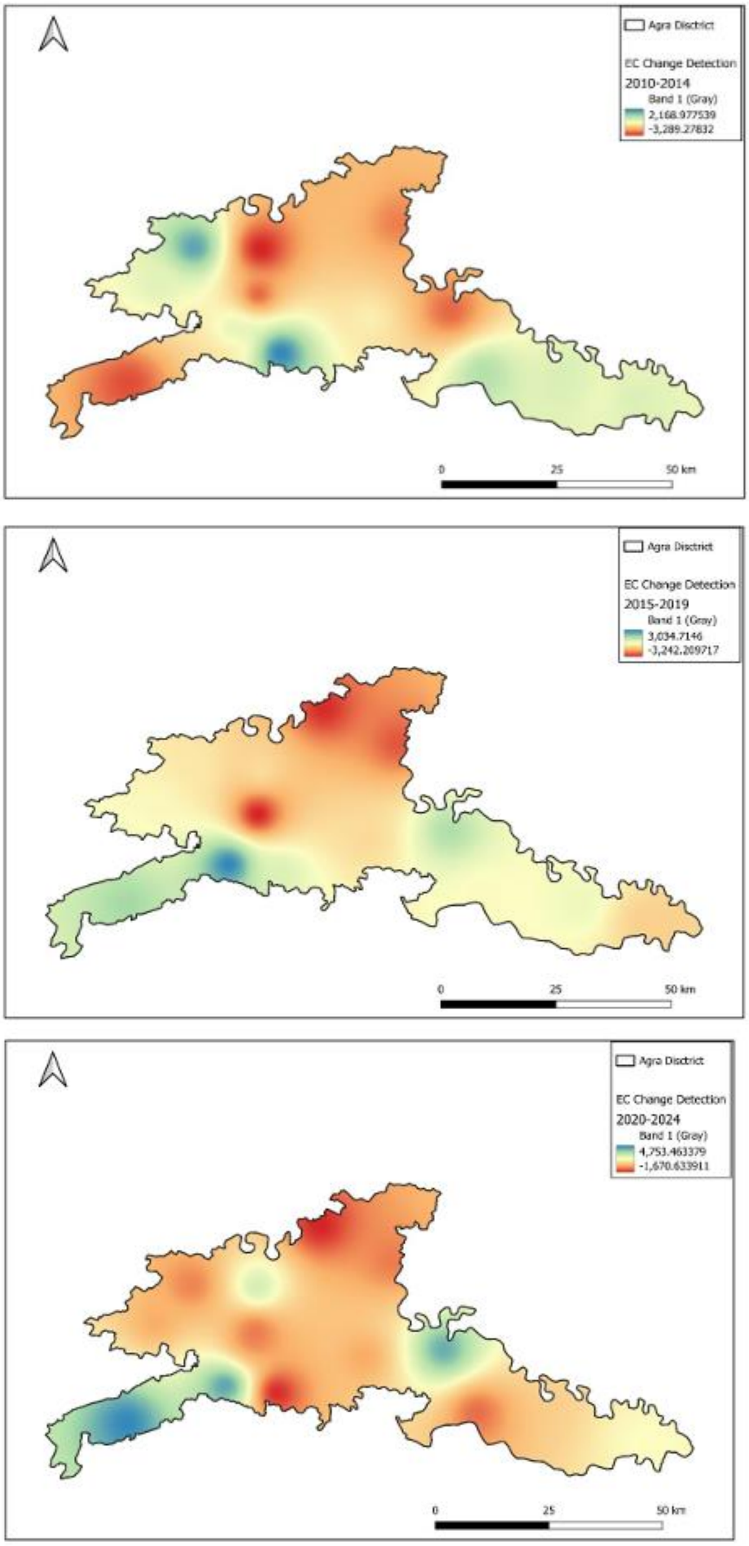


Figure 8 Change Detection of parameter Electrical Conductivity (EC) (for year 2010 to 2014, 2015-2019 & 2020-2024)

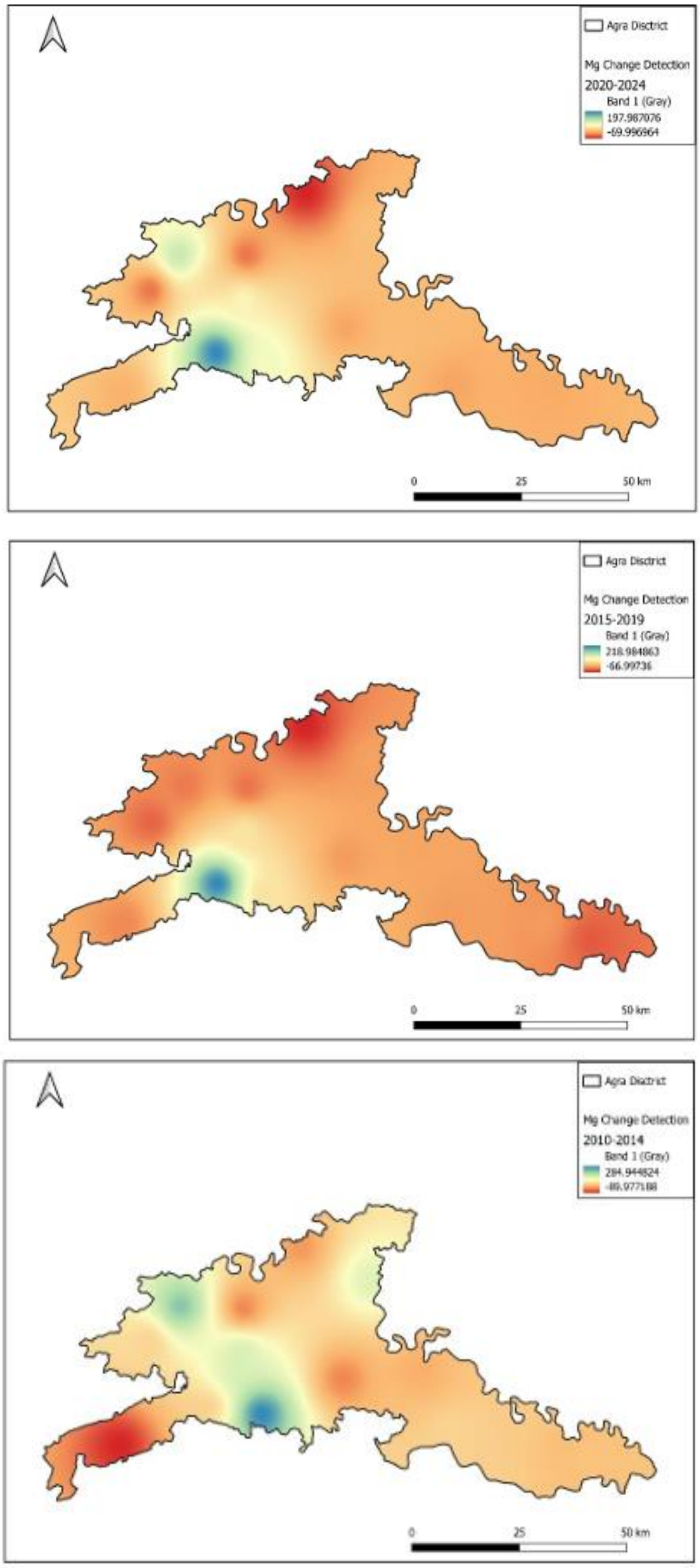


Figure 9 Change Detection of parameter Magnesium (Mg2+) (for year 2010 to 2014, 2015-2019 & 2020-2024)

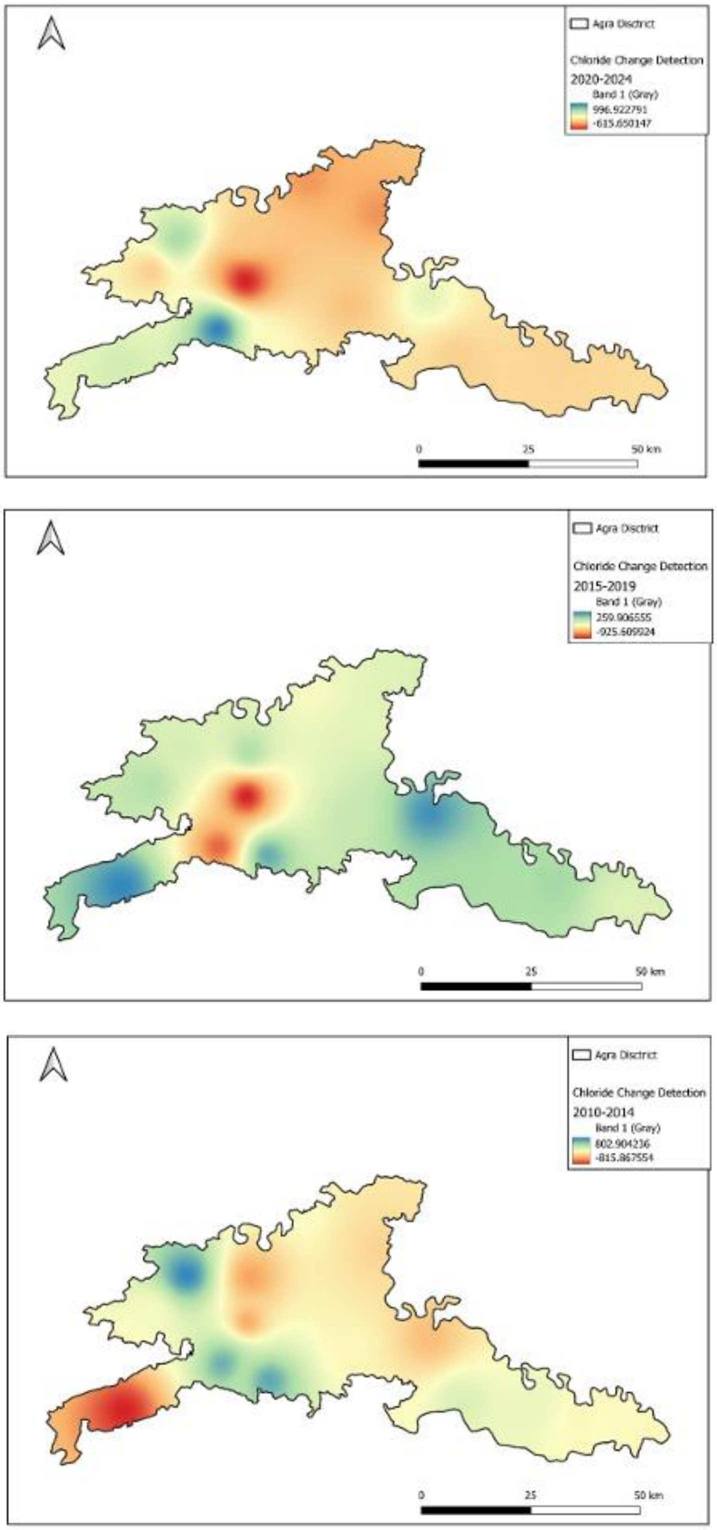


Figure 10 Change Detection of parameter Chloride (Cl-) (for year 2010 to 2014, 2015-2019 & 2020-2024)

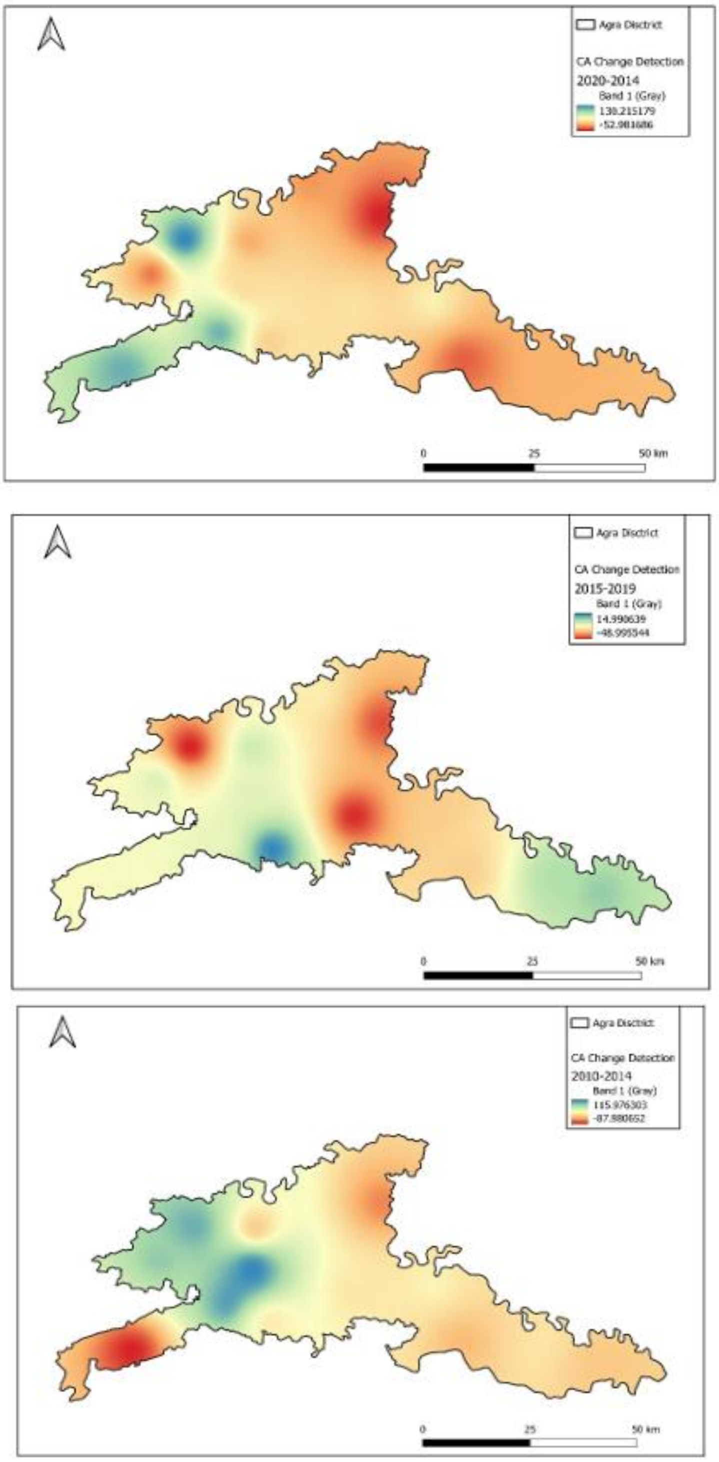


Figure 11 Change Detection of parameter Calcium (Ca2+) (for year 2010 to 2014, 2015-2019 & 2020-2024)

3. Results and Discussion

It was illustrated that with Chloride parameter some blocks among 14 exceeded the limits in certain years between 2010 to 2024. In parameter chloride it was found that the highest change with years occurred in year 2013-2014 and lowest change was detected in year 2010-2024 as illustrated in graph (Figure 12). With Magnesium parameter some exceeded the permissible limit, went above the desirable limit of 30 mg/L. Whereas in the change detection for parameter magnesium with 2010 as base year when the cumulative year maps were prepared it was found that the maximum change was in year 2013-2018 and lowest change detection was in year 2010-2024 as illustrated in graph (Figure 13). With Electrical Conductivity (EC) parameter, highest changes were in 2014-2018. For Calcium, highest changes were in 2016-2018. For pH, variations were minimal but notable in southern blocks. It can be examined that for parameters chloride and magnesium the highest changes occurred with base year 2010 was in year 2013-2014 and 2013-2018 respectively. Blocks Akola, Jagner, Kheragarh and Achhnera showed the most pollution.

Figure 12 Graph of Highest and Lowest Change Detected for Parameter Chloride

Figure 13 Graph of Highest and Lowest Change Detected for Parameter Magnesium

Figure 14 Graph of Highest and Lowest Change Detected for Parameter Electrical Conductivity (EC)

Figure 15 Graph of Highest and Lowest Change Detected for Parameter Calcium

Figure 16 Graph of Highest and Lowest Change Detected for Parameter pH

4. Conclusion

The study of Agra district of 14 blocks illustrated that from lowest to highest the average Chloride, Magnesium, EC, Calcium & pH ranged from 8.97 to 58.7, 48.57 to 33.05, 500 to 3000 µS/cm, 50 to 200 and 6.5 to 8.5 in mg/L respectively. It was also found that with Chloride parameter some blocks among 14 exceeded the limits in certain years between 2010 to 2024. With Magnesium parameter some exceeded the permissible limit, went above the desirable limit of 30 mg/L. By combining information on water quality and urban population density, one can map the geographic distribution of human health risks. Urban populations in and around the Trans-Yamuna area have been noted to be a possible "hot spot" for health risks. As a result, specific actions are required to stop anthropogenically induced groundwater contamination in these locations. For the parameter Chloride the trans and cis Yamuna areas surpassed the permissible limits in some years and showed gradual ups and downs in almost all years between 2010 to 2024. Whereas with parameter Magnesium some exceeded the limit and went above the desirable limit. Finding areas that have changed in magnitude or direction, typically over time, was the goal of the change detection. Highest change occurred for parameters Chloride and Magnesium were in year 2013-2014 with 42.9832 and 2013-2018 with 44.0413; respectively. It was noted that the highest possible changes were for period 2013–2018-time range. Groundwater contamination in the Agra district requires extensive treatment. The measures can guarantee that water will be safe to consume for an extended period.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper.

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