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(Research Article)

Analysis of groundwater parameters in Lucknow, Uttar Pradesh using GIS-based & change detection maps

Unnati Chaudhary *, Asit Singh and Saumya Singh

Department of Civil Engineering, Institute of Engineering and Technology (IET), Lucknow-226021, Uttar Pradesh, India.

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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 Lucknow 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 Lucknow district, all the 8 blocks are considered for the evaluation with parameters Magnesium and Chloride with which 22 spatial maps are prepared from ArcGIS 10.8.2 software (2021). The further assessment was carried out with change detection for the years 2011 to 2021; with year 2011 as the base year the 20 change detection maps are prepared with the help of ArcGIS Pro software (2023) the data for the same has been taken from the Central Ground Water Board (CGWB) and Groundwater Year Book, Uttar Pradesh. It was found that the highest change value with 44.0413 in Chinhat block in year 2011 intersection with 2019 for parameter magnesium and least change was in 2011 intersection with 2021 with -24.2411 in Sarojini Nagar block. 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 Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^-, and $SO_4{}^{2-}$ 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, pollution modelling, and climate GIS findings may provide useful information regarding high temperatures. Patch or risk distribution in limited geographic space for exploratory research. [5],[6] and [7] have

* Corresponding author: Unnati Chaudhary

previously researched the health risks of polluted water intake. 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 eight different Lucknow district, Uttar Pradesh, India, blocks: Bakshi-ka-Talab, Chinhat, Mal, Malihabad, Gosaiganjh, Mohanlalganjh, Sarojini Nagar, and Kakori, with a focus on chloride and magnesium distribution and contamination. The permissible limits are considered according to WHO: 2004 [9] and IS: 10500:2012 [10].

2. Materials and methods

2.1. Study Area

Lucknow district covers approximately 2525 km^2 [11] and is located between 26°30' to 27°10′ N latitudes and 81°0′E longitude (Figure 1) at heights between 103 and 130 meters above mean sea level. According to the Directorate of Census Operations, Uttar Pradesh [12] the official census 2011 for the Lucknow district, the total population of the district was 4,589,838 lakhs. The Gomti River separates the study area into two sections: Trans-Gomti and Cis-Gomti, which occupy the city's northern and southern halves, respectively. The Lucknow urban region is a part of the Cis-Gomti basin 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 Gomti 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].

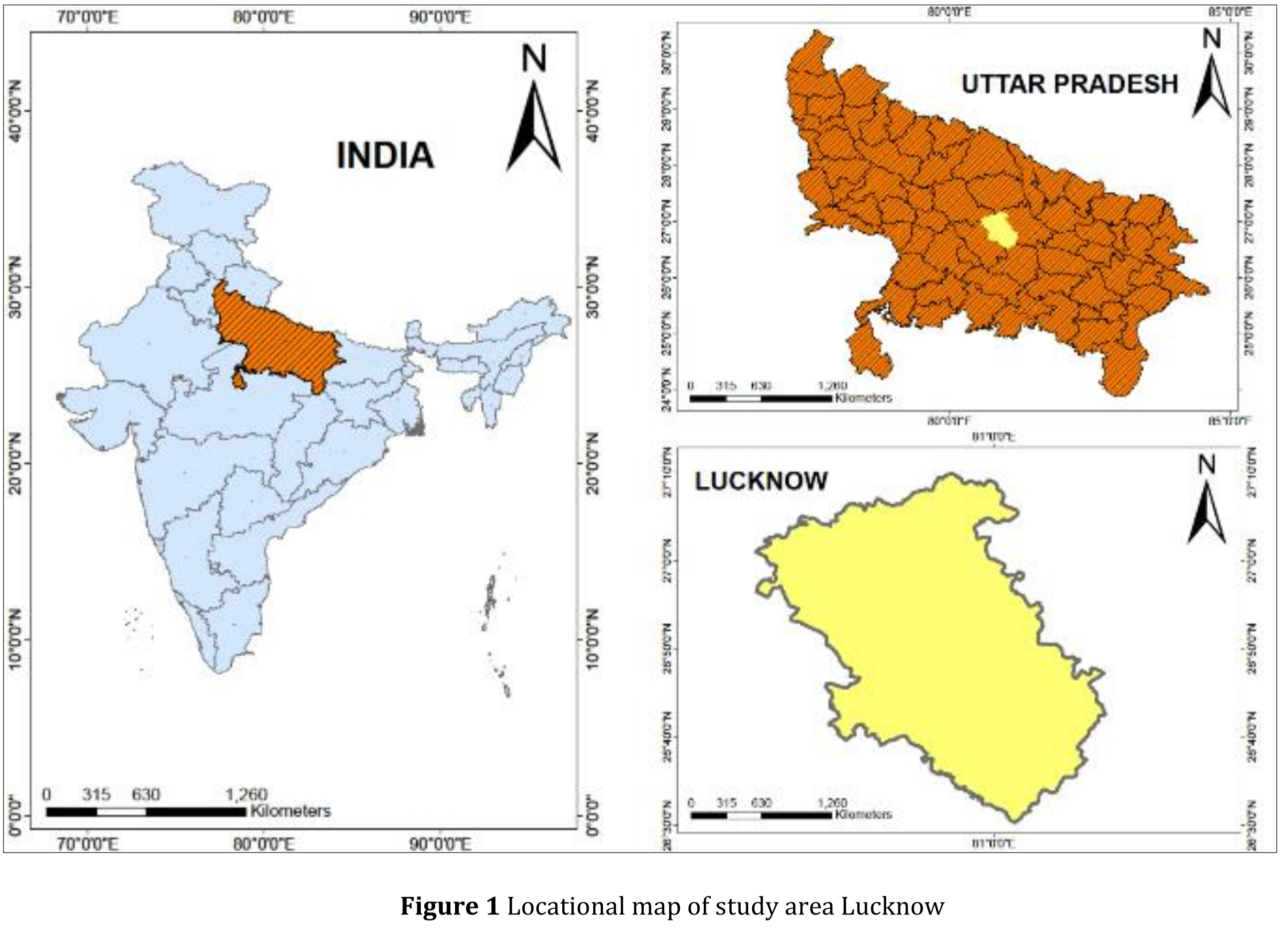

Figure 1 Locational map of study area Lucknow

2.2. Data Collection and Parameters

Almost data for the considered parameters i.e.; Magnesium and Chloride are taken for the year 2011 to 2018 from the Central Ground Water Board (CGWB) [14]. The data of ground water quality of year 2019 to 2021 are taken from the Ground Water Year Book, Uttar Pradesh [15]. A complete 11 years of data for the selected 2 parameters for district Lucknow is considered. The location marked on maps are according to the year books for 8 blocks of Lucknow district which are Bakshi-ka-Talab, Chinhat, Mal, Malihabad, Kakori, Mohanlalganjh & Gosaiganjh (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).

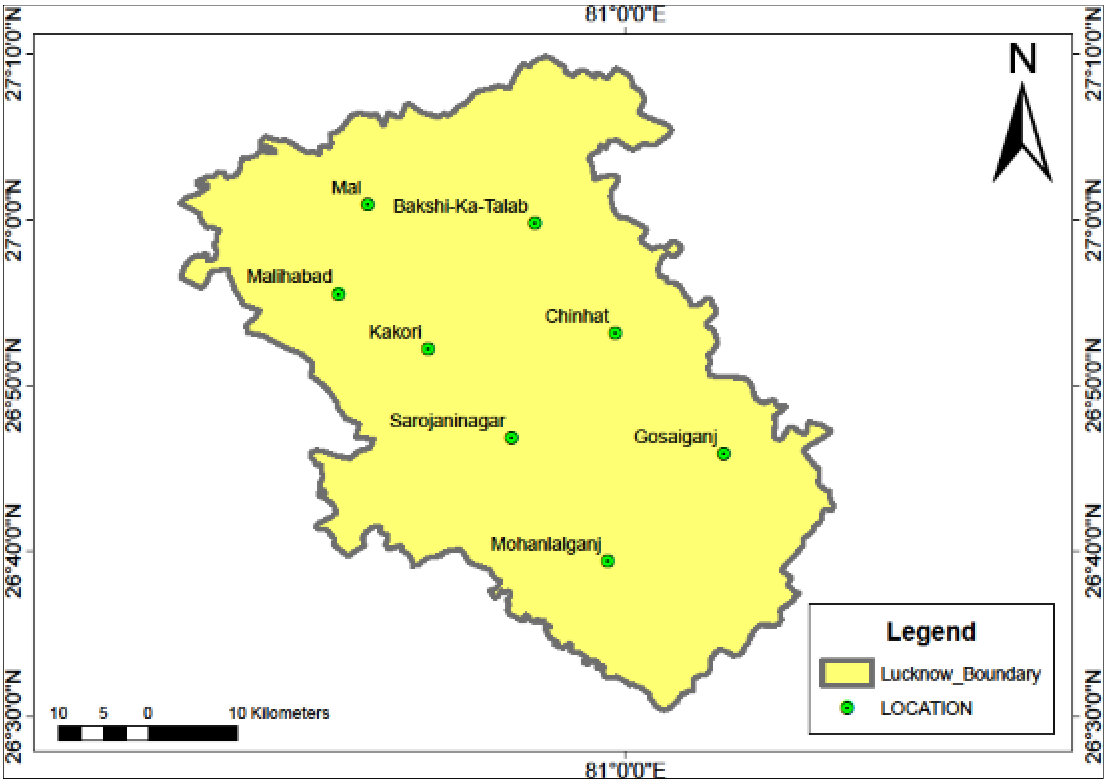

Figure 2 Blocks of Lucknow District

2.3. Visualization and Analysis

2.3.1. GIS Based Spatial Mapping

GIS can serve as a powerful tool for water quality modeling. Using GIS, you can create various thematic maps to help understand and manage water resources. In this study, 22 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-45N with geographic projection of World-WGS-1984; for parameters chloride and magnesium in Figure 3,4 &5 and Fig.6,7 &8 respectively.

Spatial Maps of Parameter Chloride (Cl^-)

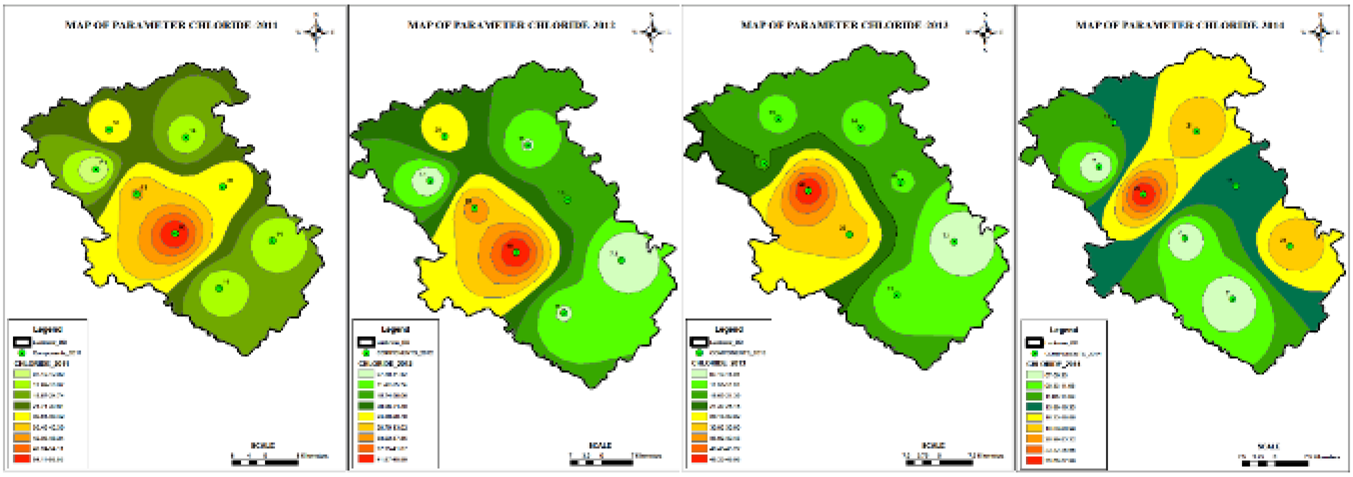

Figure 3 Spatial Maps of parameter Chloride (2011 to 2014)

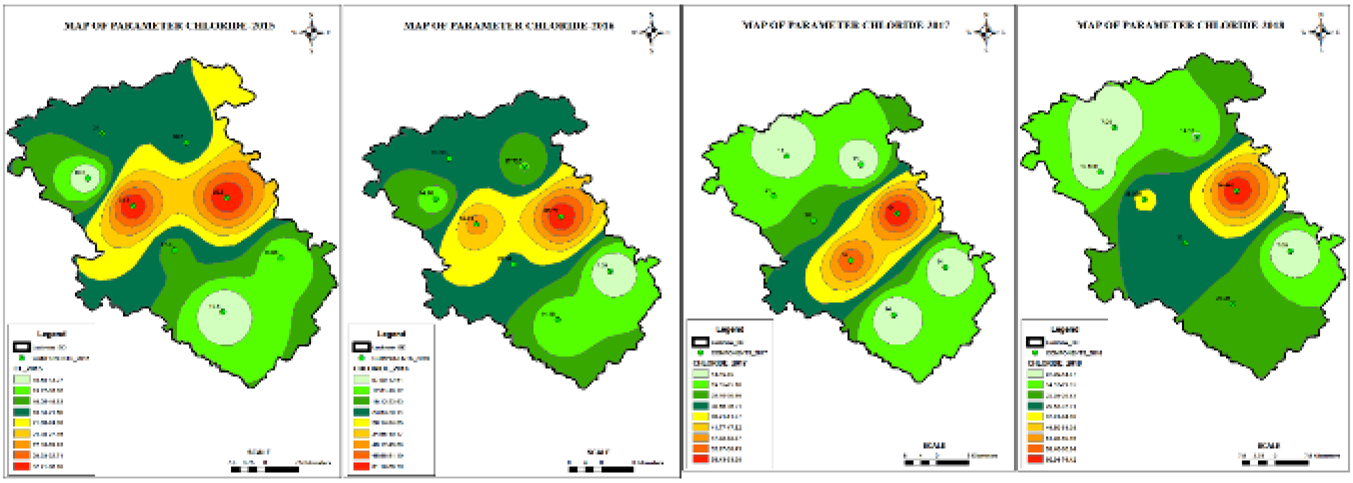

Figure 4 Spatial Maps of parameter Chloride (2015 to 2018)

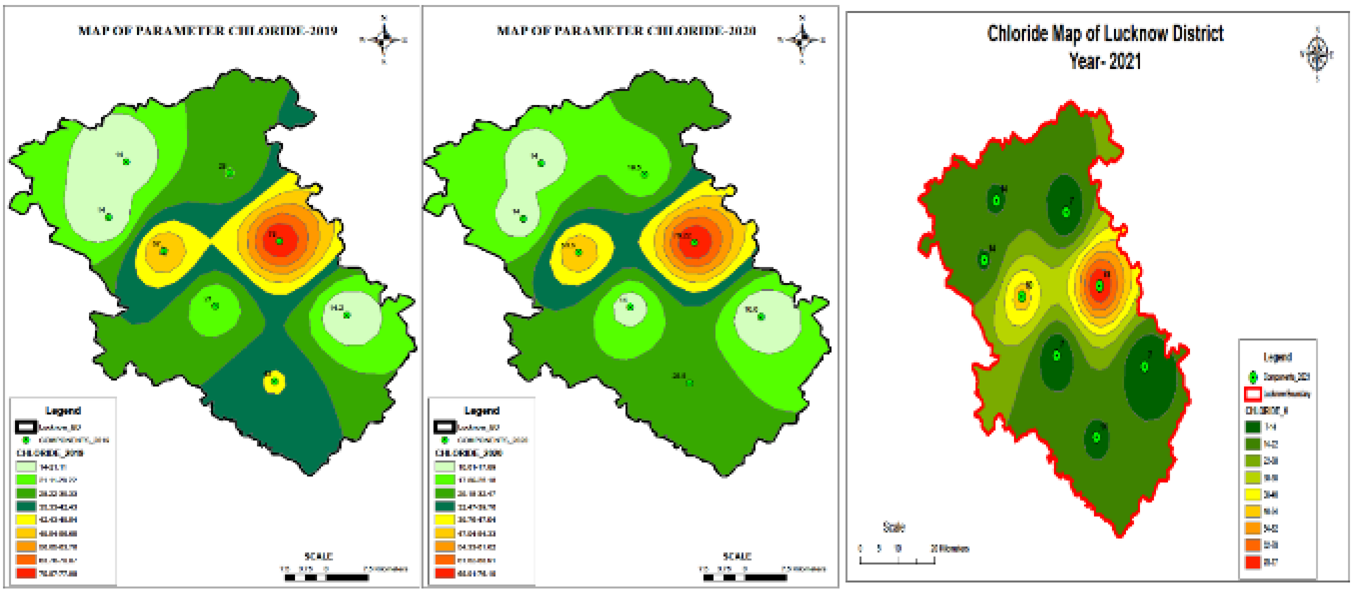

Figure 5 Spatial Maps of parameter Chloride (2019 to 2021)

Spatial Maps of Parameter Magnesium (Mg^{2+})

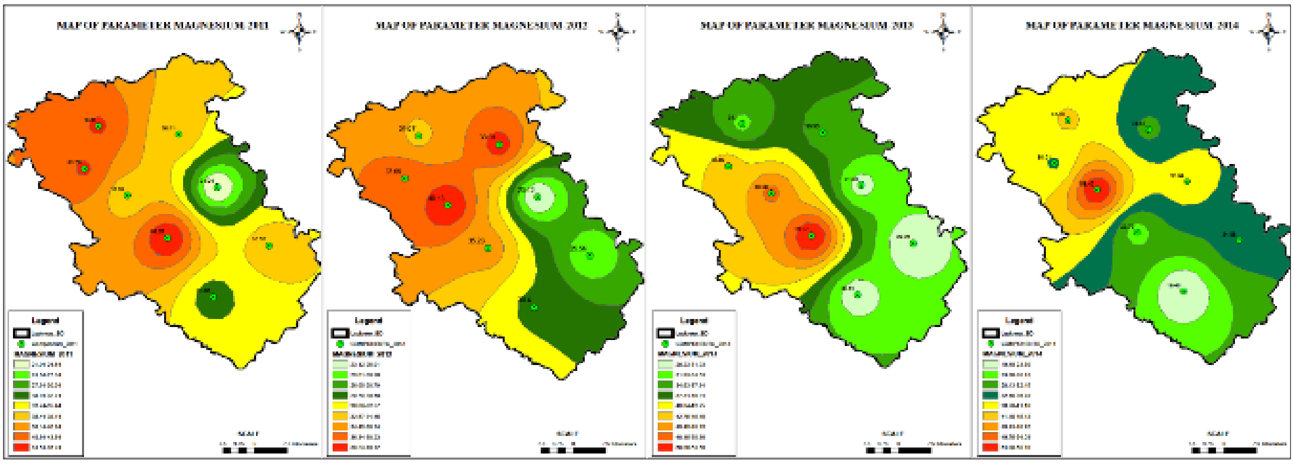

Figure 6 Spatial Maps of parameter Magnesium (2011 to 2014)

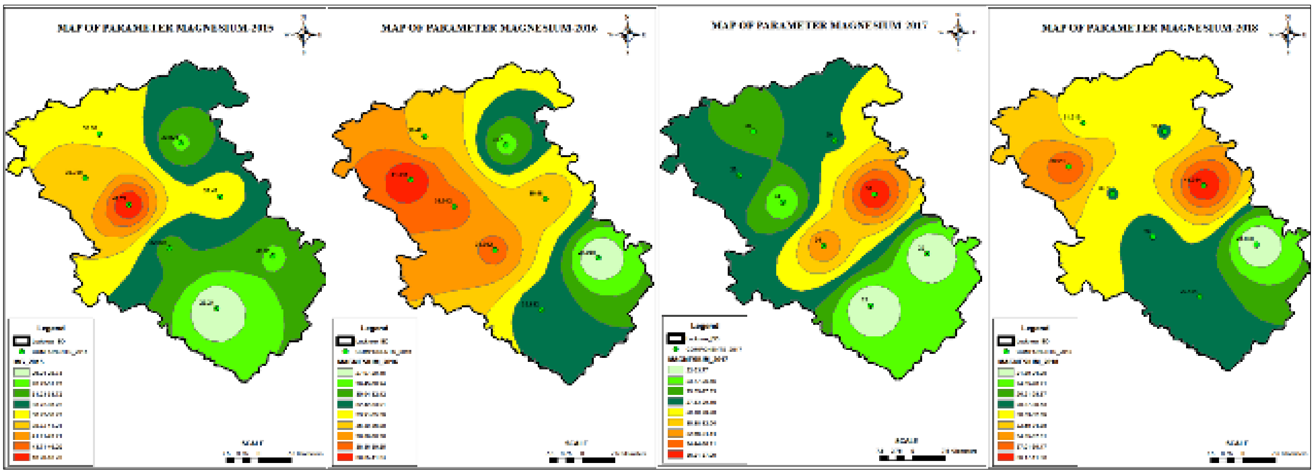

Figure 7 Spatial Maps of parameter Magnesium (2015 to 2018)

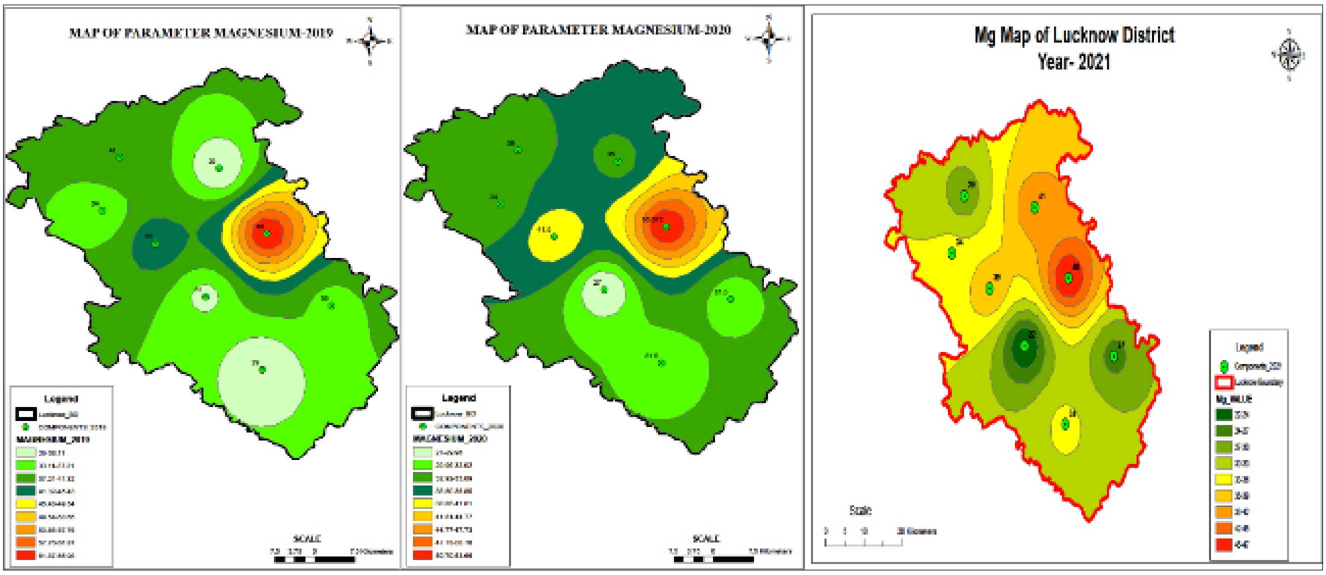

Figure 8 Spatial Maps of parameter Magnesium (2019 to 2021)

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 2011 in correspondence to the cumulative maps till the year 2021 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 parameter chloride and magnesium which are illustrated in Figure 9 & 10 and Figure 11 & 12 respectively.

Change Detection of Parameter Chloride (Cl^-)

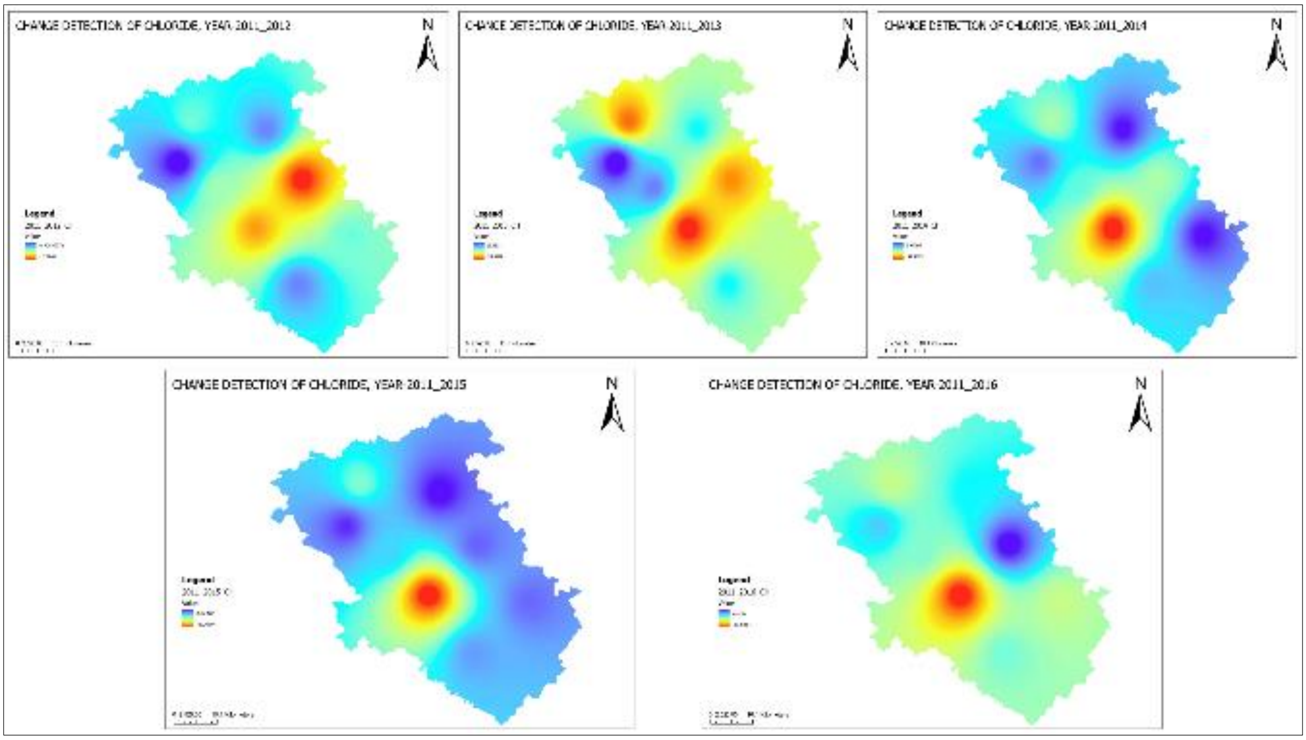

Figure 9 Change Detection of parameter Chloride (till 2016)

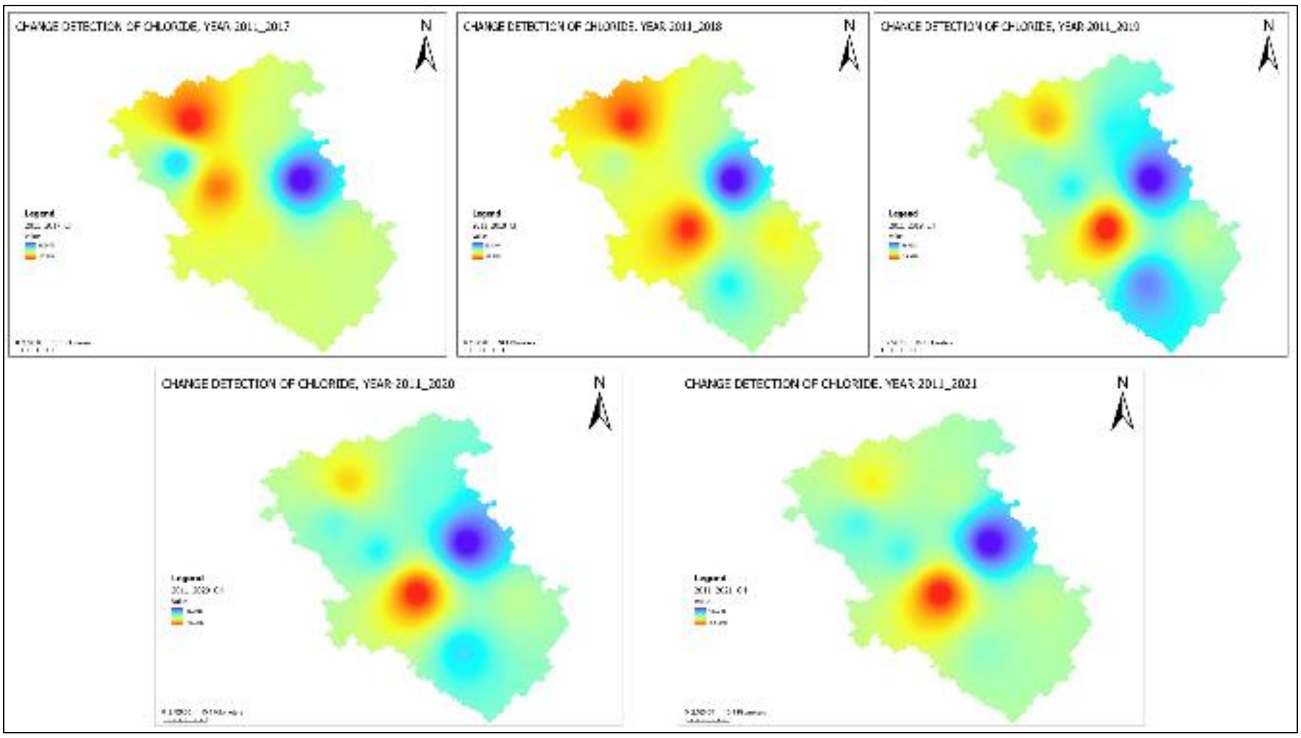

Figure 10 Change Detection of parameter Chloride (from 2017 till 2021)

Change Detection of Parameter Magnesium (Mg^{2+})

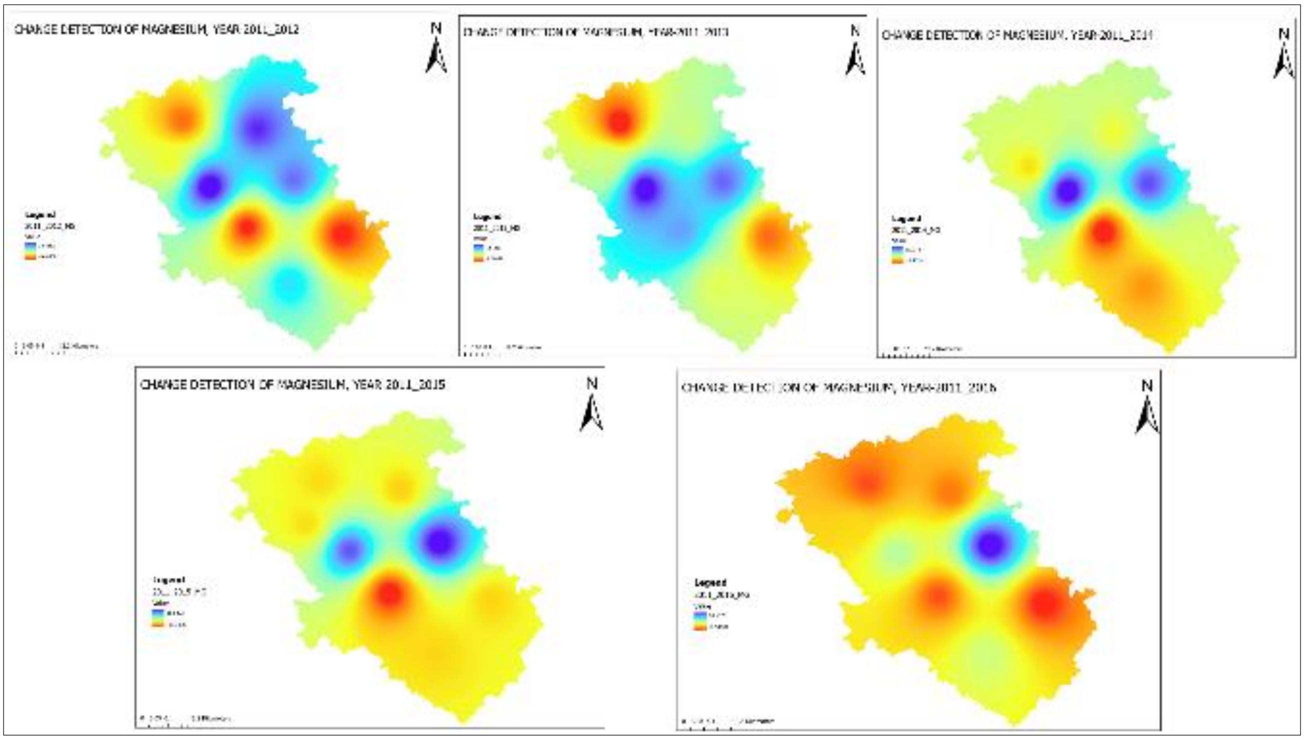

Figure 11 Change Detection of parameter Magnesium (till year 2016)

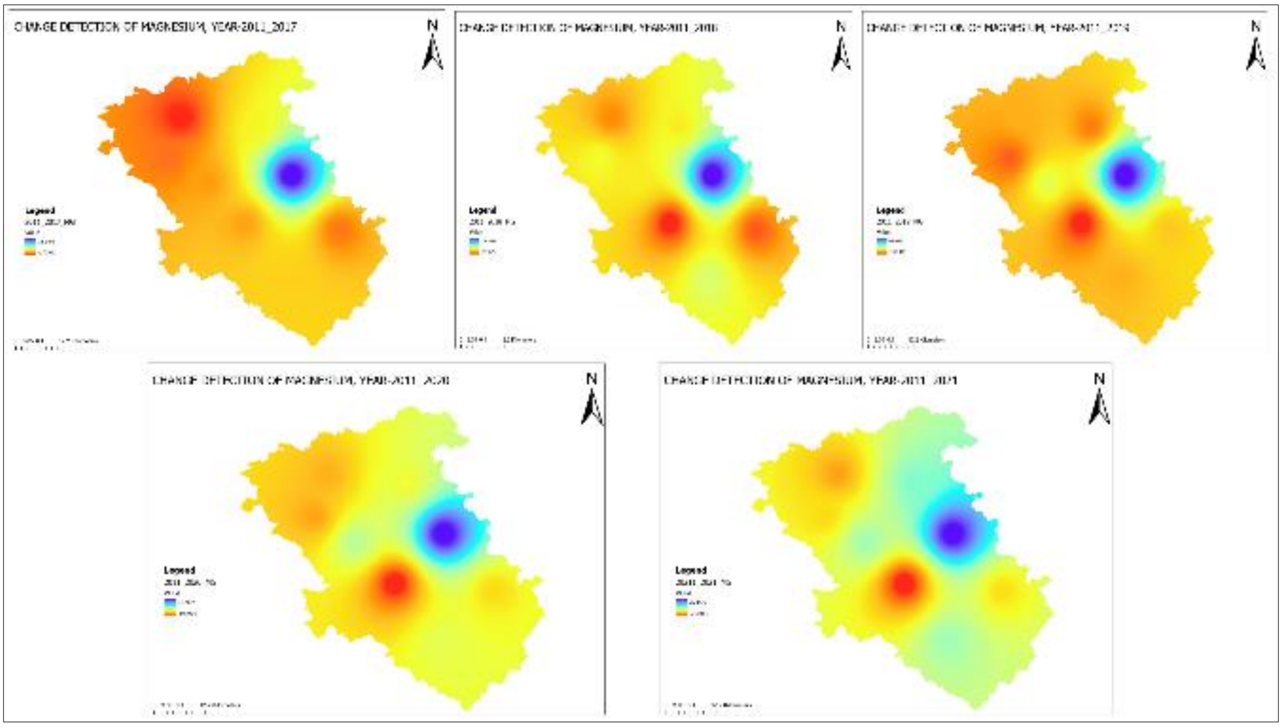

Figure 12 Change Detection of parameter Magnesium (from year 2017 till year 2021)

3. Results and discussion

It was illustrated that with Chloride parameter absolutely no block among 8 exceeded the limits & even did not cross the 100 mg/L mark in any year between 2011 to 2021). In parameter chloride it was found that the highest change with years occurred in year 2011-2019 and lowest change was detected in year 2011-2021 as illustrated in graph (Figure 13). With Magnesium parameter none exceeded the permissible limit, went above the desirable limit of 30 mg/L. Whereas in the change detection for parameter magnesium with 2011 as base year when the cumulative year maps were prepared it was found that the maximum change was in year 2011-2019 and lowest change detection was in year 2011-2014 as illustrated in graph (Figure 14). It can be examined that for both parameters' chloride and magnesium the highest changes occurred with base year 2011 was in year 2011-2019.

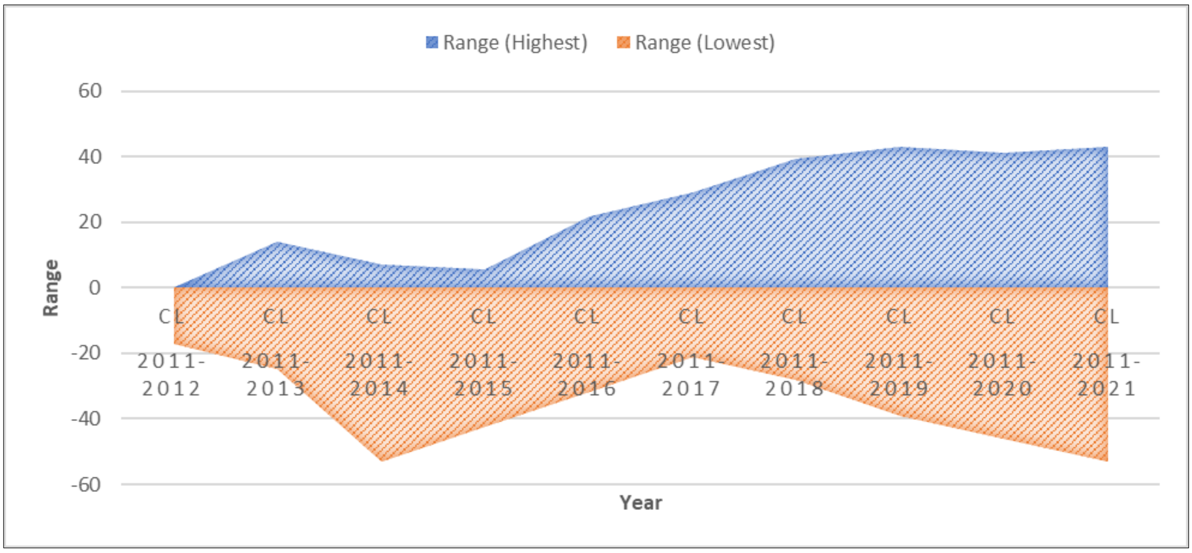

Figure 13 Graph of Highest & Lowest Change Detected for Parameter Chloride

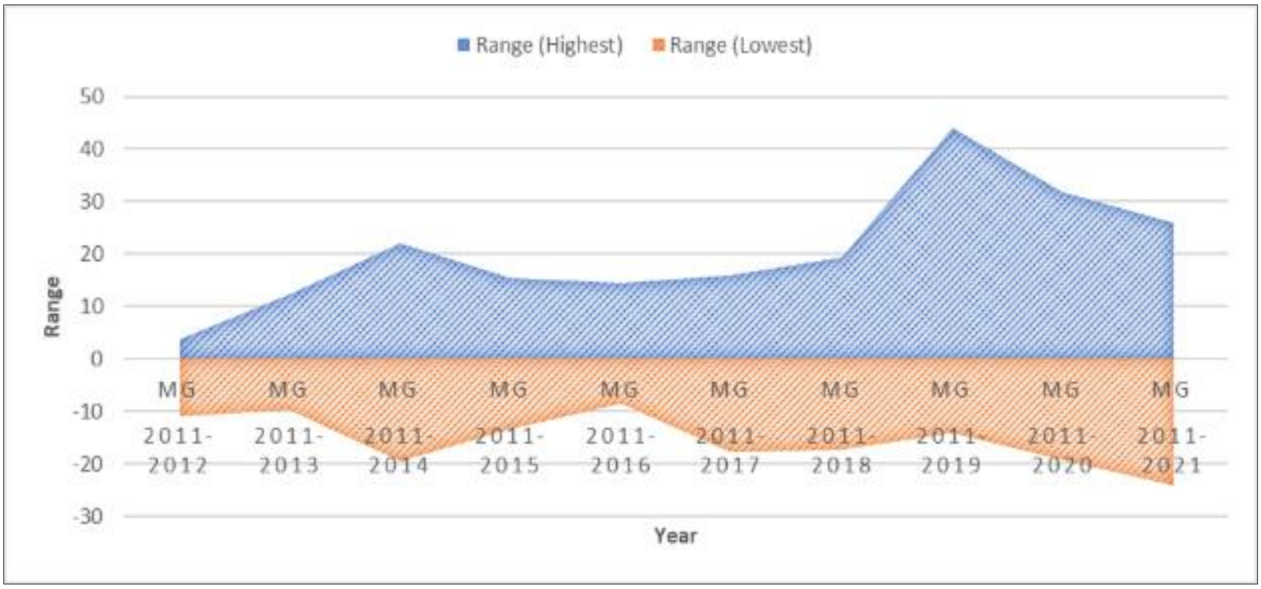

Figure 14 Graph of Highest & Lowest Change Detected for Parameter Magnesium

4. Conclusion

The study of Lucknow district of 8 blocks illustrated that from lowest to highest the average Chloride, & Magnesium ranged from 8.97 to 58.7 and 48.57 to 33.05 in mg/L respectively. It was also found that that with Chloride parameter absolutely no block among 8 exceeded the limits & even did not cross the 100 mg/L mark in any year between 2011 to 2021. With Magnesium parameter none 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-Gomti 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 Gomti areas did not surpass the permissible limits but showed gradual ups and downs in almost all years between 2011 to 2021. Whereas with parameter Magnesium none exceeded the limit and went 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 2011-2019 with 42.9832 and 2011-2019 with 44.0413; respectively. It was noted that both the highest possible changes were for period 2011–2019-time range. Groundwater contamination in the Lucknow district requires extensive treatment. The measures can guarantee that water will be safe to consume for an extended period.

Compliance with ethical standards

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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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