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DEVELOPMENT OF GIS-BASED MAPS AND CHANGE DETECTION FOR GROUNDWATER QUALITY ASSESSMENT OF LUCKNOW, UTTAR PRADESH

Unnati Chaudhary[1], Asit Singh[2], Saumya Singh[3]

[1,2,3]Department of Civil Engineering, Institute of Engineering and Technology, Lucknow-226021,Uttar Pradesh, India

Abstract: In 21st century as population is boosting by degrees, the need of water for any purposes like drinking, irrigational, etc. is becoming a copious then it was 10 or a year before. Hence assessment of ground water quality for the physico-chemical, hydro-chemical, or heavy metals for different intentions; is becoming essential then just for the informational purpose. The main intend behind the study for 8 blocks of Lucknow district is to encapsulate the groundwater quality of the district & inspect the changes that have occurred between the census year 2011 to 2021; the data is extracted from the Central Ground Water Board (CGWB) and Groundwater Year Book, Uttar Pradesh. Primarily, 33 spatial maps of groundwater quality for the selected 3 parameters; pH, Electrical Conductivity (EC) & Calcium (Ca^{2+}) are prepared with ArcGIS 10.8.2 (2021). Furthermore, 30 change detection maps for the same are prepared with ArcGIS Pro (2023). It was found that block Bakshi-ka-Talab and Chinhat are the most polluted blocks among. And change detection through pixel value change detection keeping 2011 as base year and cumulative maps is prepared simultaneously. The difference in change values could be ascertained with the help of graphs & maps plotted, the highest change found for parameters were in year; 2011-2018, 2011-2021 & 2011-2018; for pH, EC & Ca, respectively. The standards limit for the parameters as per Bureau of Indian Standard (BIS): IS 10500-2012 & World Health Organization (WHO) IS: 2011 are considered.

Keywords- Groundwater assessment; Spatial Maps; Change Detection; Pixel Value; BIS; WHO.

I. Introduction:

Groundwater serves as a vital source of drinking water, utilized primarily after fulfilling essential needs like basic household use, irrigation, and industrial activities. The Indian standard sets the average daily water consumption per individual at 135 liters. Human activities, such as irrigation and industrial processes, contribute to groundwater pollution. This contamination can lead to issues like insufficient drinking water, compromised water quality, elevated healthcare expenses, the high cost of providing alternative water sources, and health concerns (Nas and Berktay 2010). An imperative facet of water quality management involves assessing groundwater quality and its correlation with water management practices. Prior to utilizing water for specific purposes, the permissible parameters should be defined based on the intended use (Kavurmaci 2016). The term "water quality" pertains to the analysis of water's physical and chemical composition, determining its appropriateness for domestic, irrigation, and commercial applications (Dwivedi and Pathak 2007). Numerous factors directly impact water quality, including dissolved minerals, microalgae levels, pesticides, herbicides, heavy metals, and other pollutants. These factors can influence the flavor, scent, and clarity of groundwater (Cordy 2001). Effective water resource management hinges on water quality, as it plays a crucial role in balancing groundwater with healthy ecosystems (Banerjee and Srivastava 2009). From a water safety perspective, consistent monitoring of water quality is imperative (Foster and Willetts 2018). Such monitoring and data analysis are essential to identifying potential health risks (Rivera-Núñez et al., 2018). The process of urbanization, a historical inevitability, involves population concentration in limited spaces (UN, 2004). Urban development triggers alterations that impact the environment, encompassing hydrology, ecology, water resources, and vegetation. The rapid urban expansion continues to jeopardize groundwater quality through overexploitation and improper practices (Mohrir et al., 2002). Lucknow, the capital of populous Uttar Pradesh state, stands out as one of India's swiftly growing cities. Encompassing 2,525 square kilometers within the Middle Ganga Plain as per GW Brochure of Lucknow District, Uttar Pradesh, Lucknow district lies between latitudes 26° 30' to 27° 10' north and longitude 81°0' east, as per the report by Directorate of Census

Operations in Uttar Pradesh total population of Lucknow is 4,589,838. The city grapples with shifts in environmental conditions as rapid growth impacts land, water, housing, transportation, healthcare, and education (Gyananath et al., 2001).

Lucknow's population has surged dramatically, growing from 497,000 in 1951 to 2.267 million in 2001, 2.714 million in 2006, and 3.306 million in 2011—an increase of 456% over five decades (Anju Verma et al., 2013). The annual population growth rate for Lucknow (UA) is 7.12% (Lucknow Master Plan, 2010 & Anju Verma et al., 2013). Such population growth significantly impacts the region's natural resources, particularly water quality and availability. Maintaining clean water is paramount for a healthy life, yet excessive and inappropriate usage of groundwater results in a decline in water quality. In recent times, groundwater has gained importance for drinking, industrial, and irrigation purposes. Geographic Information Systems (GIS) offer effective tools for mapping, monitoring, and detecting changes in water quality (Ferry et al., 2003). GIS can play a pivotal role in resolving water-related issues and designing effective solutions (Skidmore et al., 2015). GIS change detection helps establish a preview mask for change computation and discern minute differences using stretch types like minimum maximum, percent clip, standard deviation, histogram equalization, and custom preview masking. A crucial requirement of raster processing and remote sensing is change detection. To find pixels that have changed because of long-term, seasonal, or abrupt changes, several rasters or photos taken at the same area at various times are compared. Using tools and raster functions offered by the Image Analyst extension, ArcGIS Pro enables you to compare rasters and determine the magnitude and kind of change. In order to identify the kind, size, and location of a change, numerous raster datasets that were typically collected for the same area at various dates are compared. Anthropogenic activity, sudden natural disturbances, or long-term climatological or environmental patterns can all lead to changes. Change detection produces a difference raster, where each pixel contains information on the type or size of the change. Change detection methods can be of numerous types according to ArcGIS Pro (2023); Comparing categorical rasters is done to find areas that have changed over time from one class to another. This is known as categorical change detection. Pixel Value Change Detection: When comparing modeled data, the goal is normally to find regions that have changed significantly or in a specific way, usually over time. Time Series Change Detection: A time series is a collection of images or rasters that have been taken over a period, typically at regular intervals, and are used to study changes to the earth's surface. Determine the spectral difference between two multiband rasters by treating the spectra of each pixel as a vector. A polygon feature class, a raster dataset, or a raster function template are the three output formats to save the final product as. In this research, GIS (ArcGIS & ArcGIS Pro) is used which quantifies the impact of change on ground water resources in between 2011 to 2021 in Lucknow District and helps in the context of 4 visualize, analyze, and helps to understand the relationship among the measured points through mapping.

II. Methodology:

The research significance of the study involves the following steps: -

2.1 Study Area:

Lucknow is in Uttar Pradesh's Central Ganges Plain between 26°30' and 27°10' North and 81°0' E latitude, according to the research area map in figure-1, which is prepared using ArcGIS 10.8.2 2021. According to the Directorate of Census Operations, Uttar Pradesh the official census 2011 for the Lucknow district, the total population of the district was 4,589,838 lakhs. The Gomati River, which runs through the city, is the primary topographical feature that divides the city into the Trans-Gomati and Sis-Gomati districts. Summer, the wet season, and winter are the three distinct seasons of Lucknow's subtropical climate. From 5°C in January to 45°C at its highest point in May, the temperature varies. 1014.7 millimeters of precipitation fall on average per year in the city. The district is divided into 4 Tehsils, 8 Blocks, 835 Villages, 97 Nayay Panchayats, 511 Gram Panchayats with total area of 2525 square kilometers. For the study 8 blocks namely Bakshi-Ka-Talab, Mal, Malihabad, Kakori, Mohanlalganjh, Gosaiganjh, & Chinhat are considered (Fig-1).

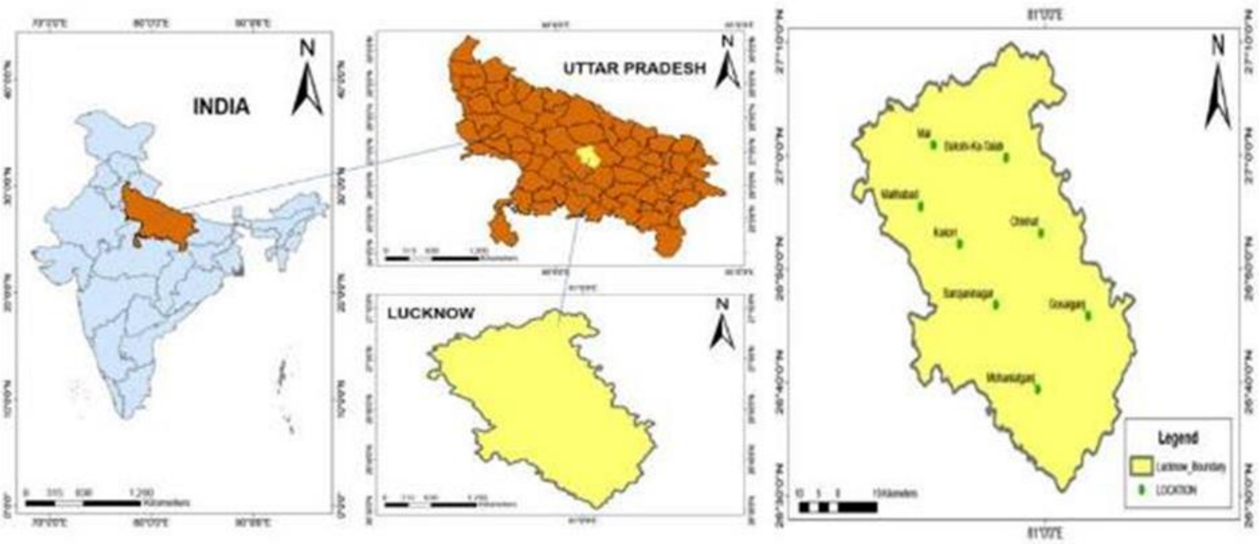

Fig-1- Locational Map

2.2 Data Collection and Parameters:

Almost the data for the considered parameters i.e.; pH, Electrical Conductivity (EC), and Calcium (Ca^{2+}) are taken for the year 2011 to 2018 from the Central Ground Water Board (CGWB). The data of ground water quality of year 2019 to 2021 are taken from the Ground Water Year Book, Uttar Pradesh. A complete 11 years of data for the selected 3 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 (Fig-1). 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:

i. GIS Based Spatial Mapping-

Modeling water quality using GIS can be quite effective. To better understand and manage water resources, you can make a variety of thematic maps using GIS. This study employs an IDW (Inverse Distance-Weighted) GIS technique for spatial interpolation. By choosing sample points from various places, the grid output values are approximated using this method. The importance of known points in the interpolated values is controlled based on their distance from the output point, and a surface mesh with theme contours is produced using a linearly weighted combination of sample points. 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. There are 33 spatial maps for years 2011 to 2021 for the parameter's pH (Fig-2a,2b), parameter EC (Fig-3a,3b) and parameter Calcium (Ca2+) (Fig-4a,4b).

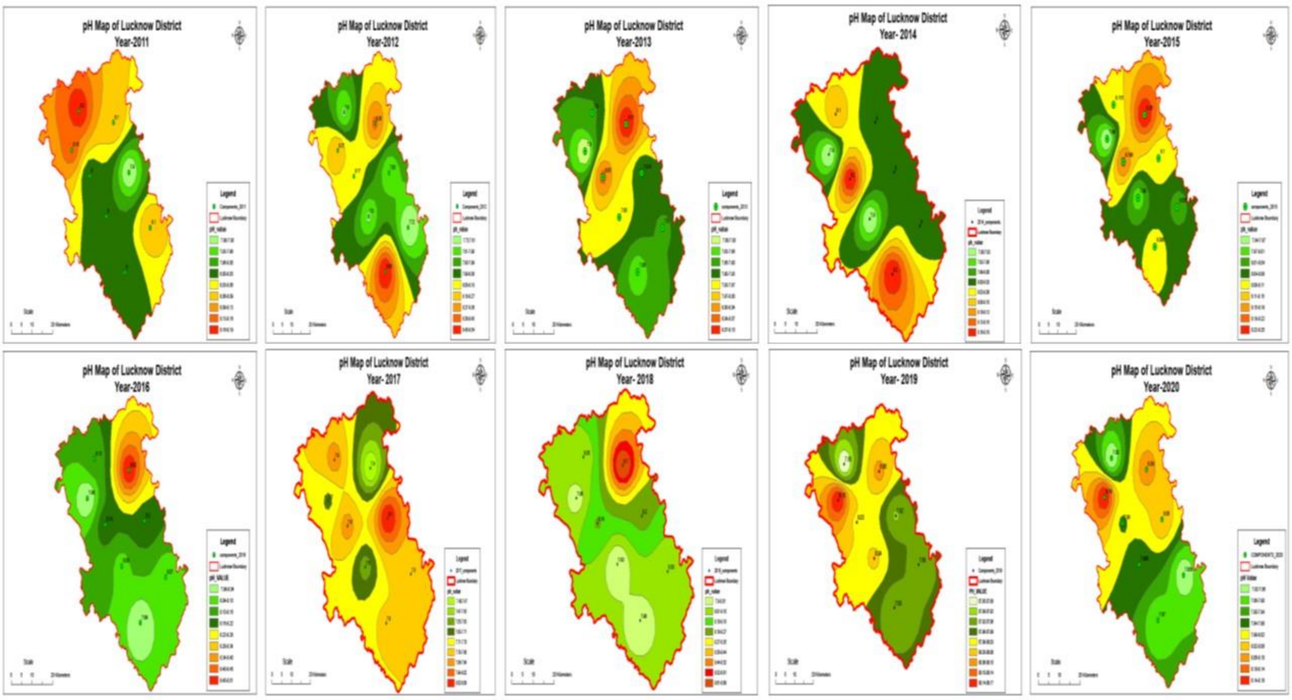

Fig-2a- Spatial Maps of parameter pH (2011 to 2020)

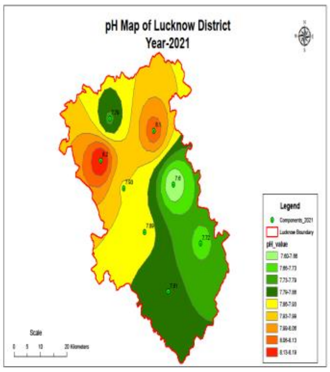

Fig-2b- Spatial Maps of parameter pH (2021)

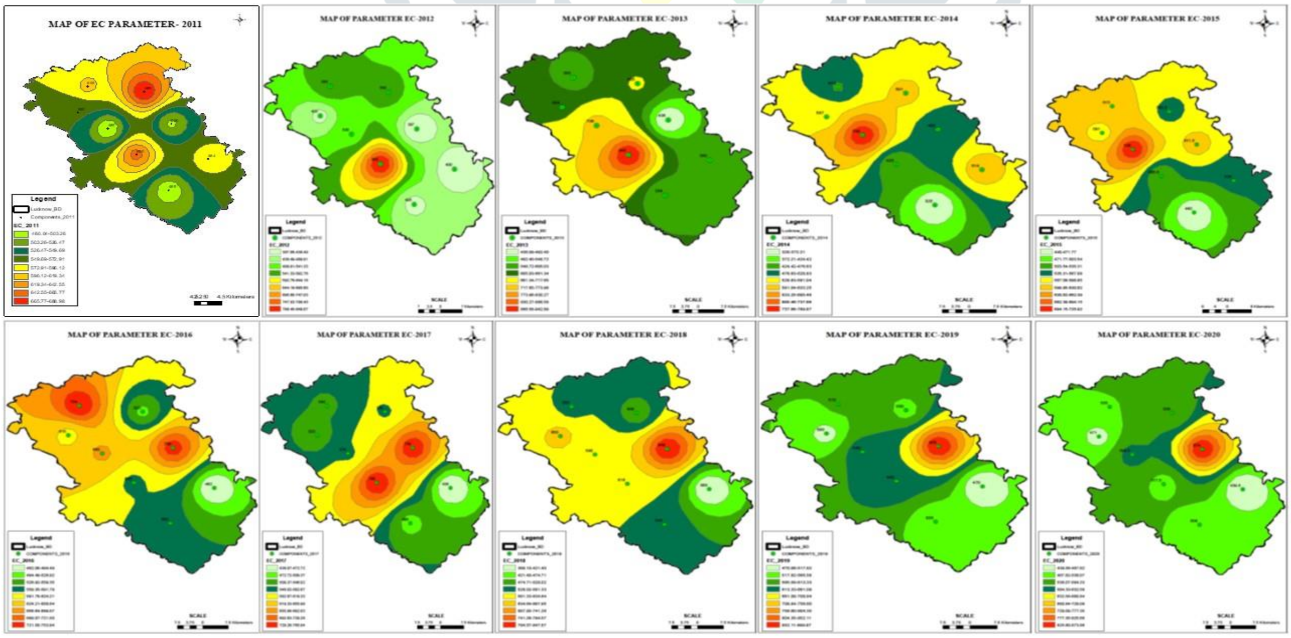

Fig-3a- Spatial Maps of parameter EC (2011 to 2020)

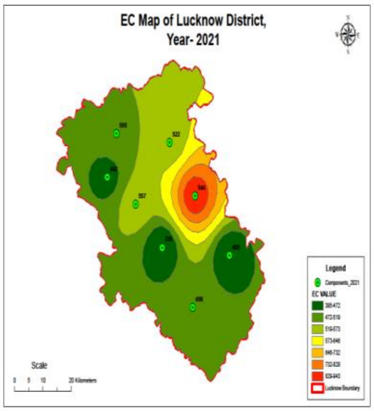

Fig-3b- Spatial Maps of parameter EC (2021)

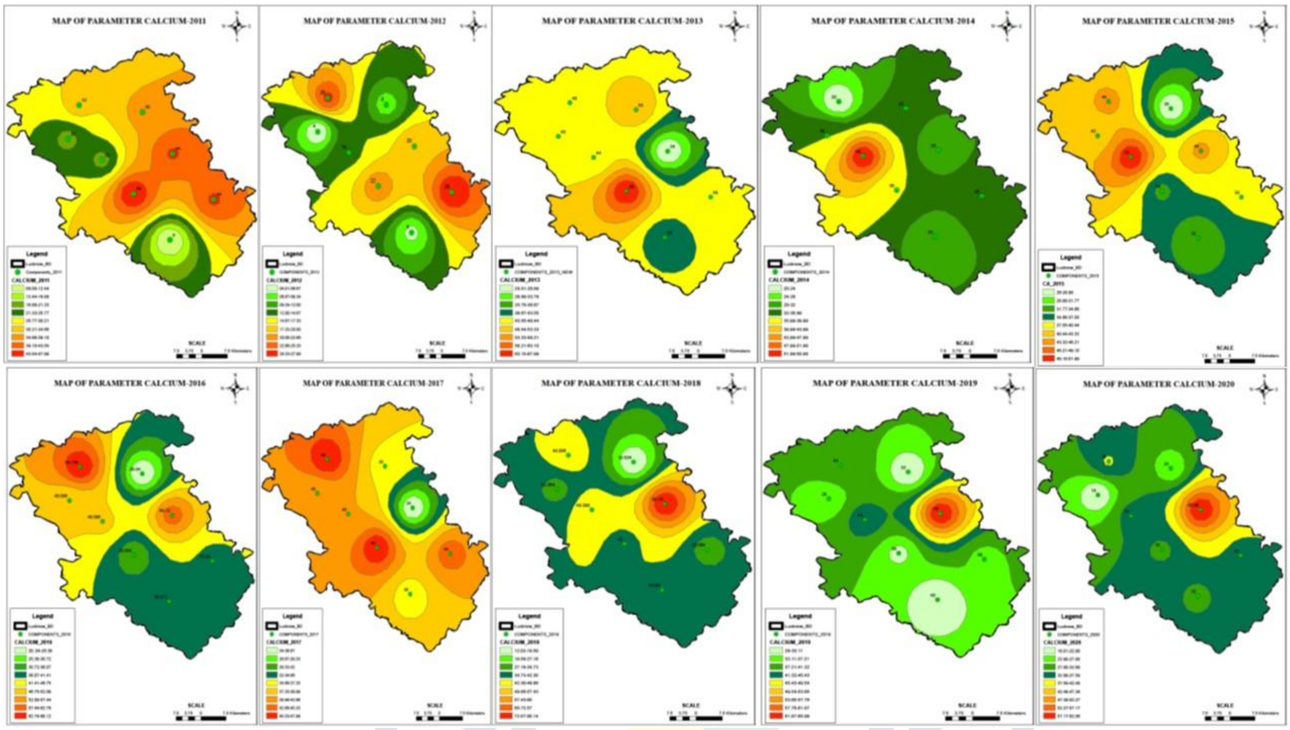

Fig-4a- Spatial Maps of parameter Ca^{2+} (2011 to 2020)

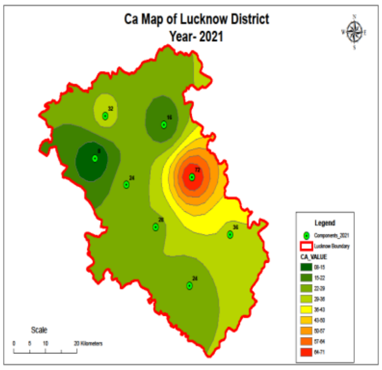

Fig-4b- Spatial Maps of parameter Ca^{2+} (2021)

ii. **GIS Based Change Detection-**

The change detection is done with the method pixel value change detection, the purpose of comparing modeled 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) extracted to compute changes. The raster template for the pixel value change detection is explained through a flow chart (Fig-5).

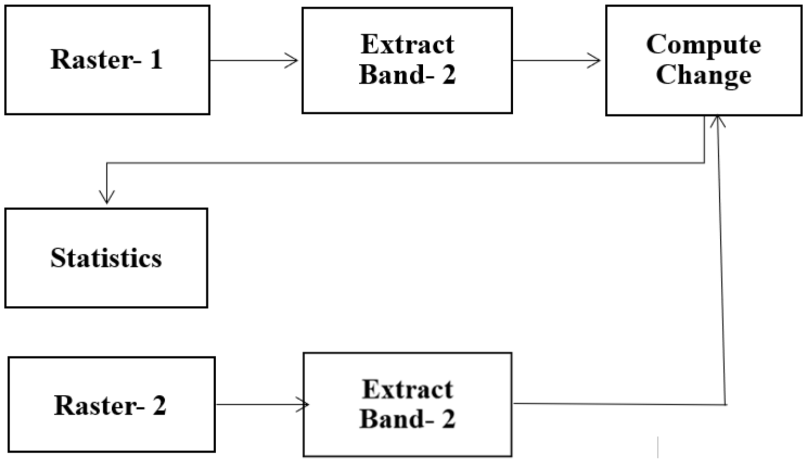

Fig-5- Raster Templet

The difference type here was absolute with single band difference method with the intersection of extent type. There are 20 intersected change detection maps for parameter pH (Fig-6), EC (Fig-7) & Calcium (Ca^{2+}) (Fig- 8).

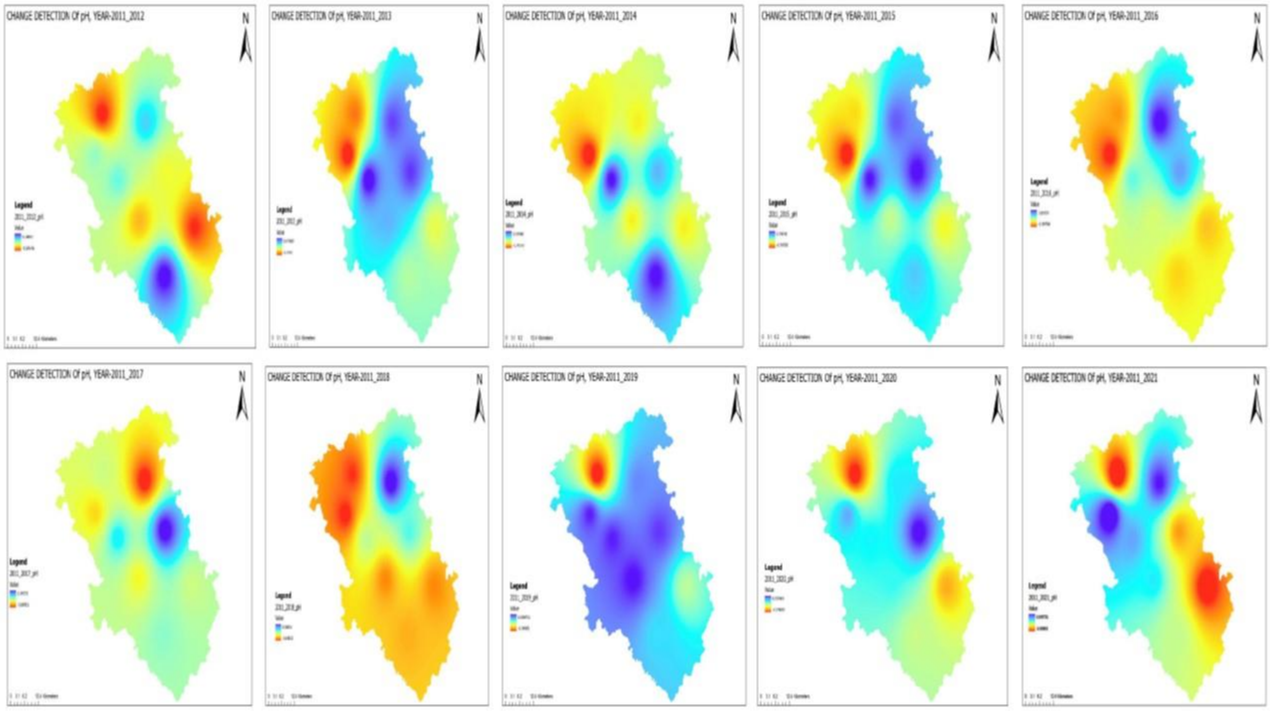

Fig-6-Change Detection of parameter pH

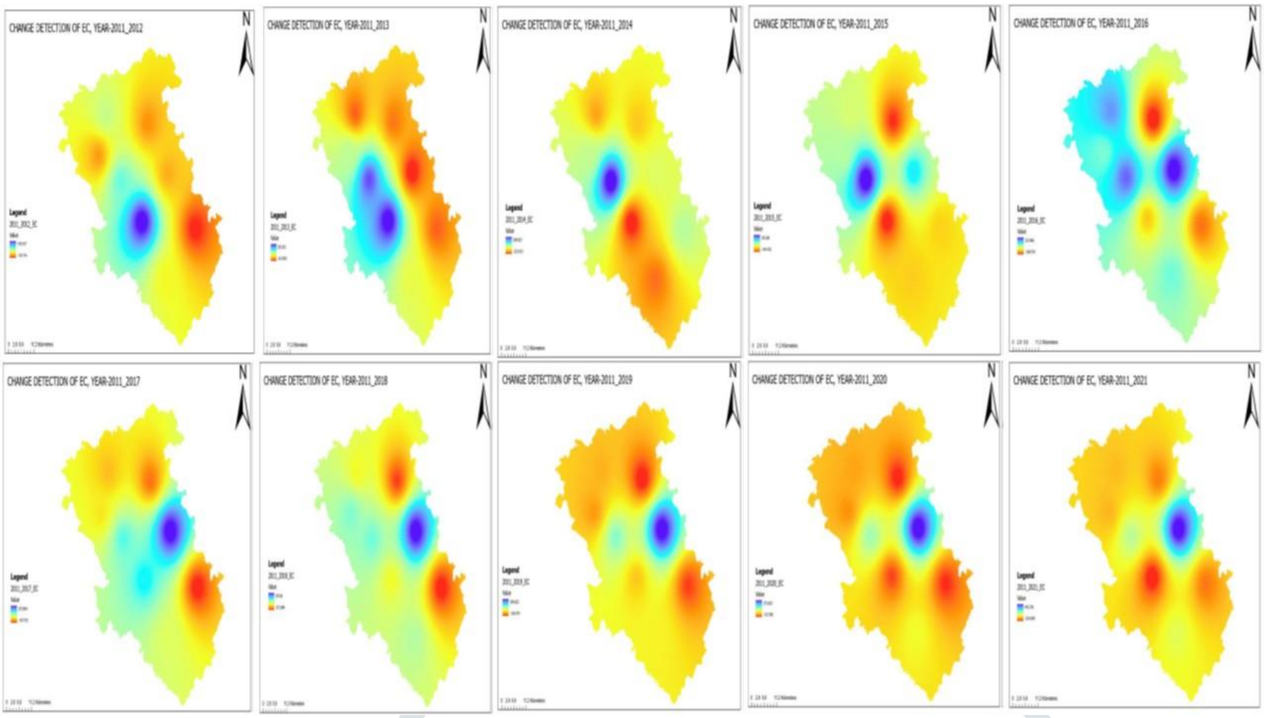

Fig-7-Change Detection of parameter EC

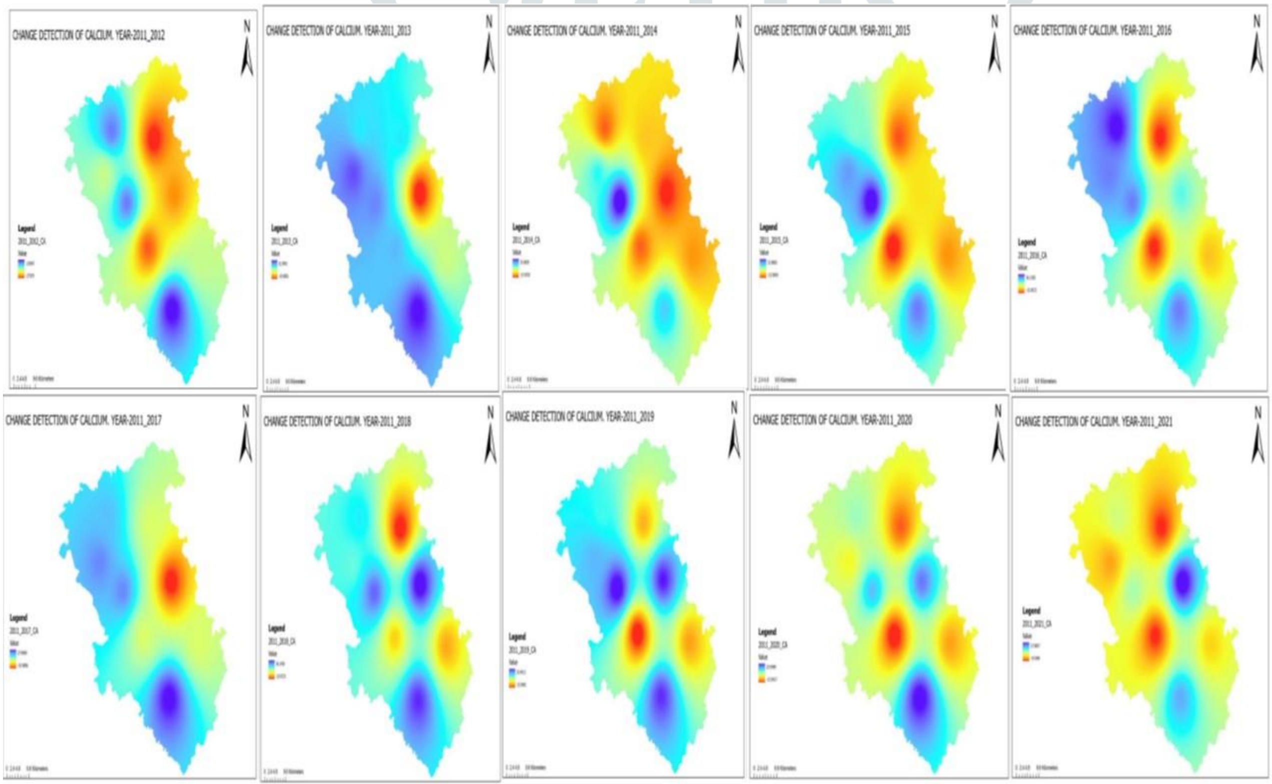

Fig-8-Change Detection of parameter Ca^{2+}

III. Results and Discussion:

This study examined the following results, the findings from this research are:

1. In the study areas of Lucknow district, it is found that out of the 8 blocks 7 blocks did not surpass the settled limits for parameters in any year between 2021 but 1 block has surpassed pH parameter's limit i.e.; Bakshi-Ka-Talab.
2. The average range (from lowest to highest) of pH for all blocks were between 7.80 to 8.28. Chinhat block shows the drastic change in the range of pH from the year 2015 and beyond the range was above 8 to 8.2 (except for year 2019 & 2021). But it was noted that in the year 2017 and almost the same in year 2021 the pH range of almost all the blocks were lesser than 8 except in the Chinhat block (Table 3.1, Fig-9).

Table 3.1: pH values of block Chinhat

YEAR	PARAMETER	LOCATION	RANGE
2011	pH	Chinhat	7.9
2012	pH	Chinhat	7.83
2013	pH	Chinhat	7.91
2014	pH	Chinhat	8
2015	pH	Chinhat	8.1
2016	pH	Chinhat	8.2
2017	pH	Chinhat	8.1
2018	pH	Chinhat	8.2
2019	pH	Chinhat	7.92
2020	pH	Chinhat	8.06
2021	pH	Chinhat	7.6

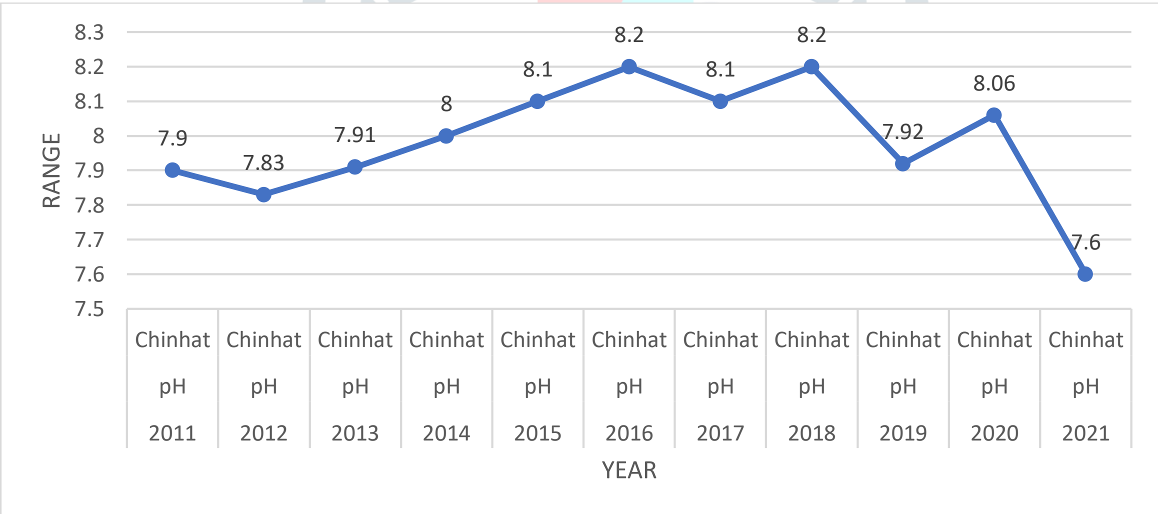

Fig-9- Graphical depiction of pH values for block Chinhat

3. The block Bakshi-ka-Talab had poor pH level from the beginning and it did not show any improvement in the year 2021 where all other blocks did but has shown the lowest value than that of all other blocks in year 2017 i.e., 7.4.
4. Year 2016 & 2018 Bakshi-ka-Talab block surpassed the permissible limit for pH by 0.2 & 0.5 respectively (Table-3.2, Fig-10).
5. In the beginning i.e., 2011 Bakshi-ka-Talab showed poor result among all the other 8 blocks while as the year passed Chinhat block became among the poorest sharing the platform with Bakshi-Ka-Talab then all other remaining 6 blocks. In some years , almost all blocks were above range of 8.

Table 3.2: Graphical depiction of pH values for block Bakshi-Ka-Talab

Year	Parameter	Location	Range
2011	pH	Bakshi-Ka-Talab	8.1

2012	pH	Bakshi-Ka-Talab	8.38
2013	pH	Bakshi-Ka-Talab	8.11
2014	pH	Bakshi-Ka-Talab	8
2015	pH	Bakshi-Ka-Talab	8.26
2016	pH	Bakshi-Ka-Talab	8.52
2017	pH	Bakshi-Ka-Talab	7.4
2018	pH	Bakshi-Ka-Talab	8.7
2019	pH	Bakshi-Ka-Talab	8.08
2020	pH	Bakshi-Ka-Talab	8.09
2021	pH	Bakshi-Ka-Talab	8.1

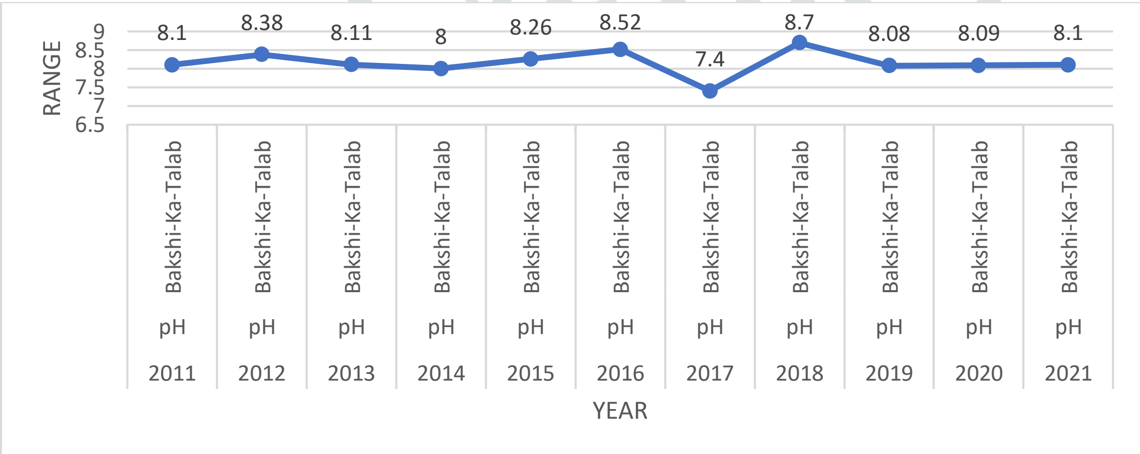

Fig-10- Graphical depiction of pH values for block Bakshi-Ka-Talab

6. Electrical Conductivity parameter absolutely no blocks among 8 exceeded the limits & even was not near by the sensitive limit & on an average the highest value it went was of 825.63 µmhos/cm.
7. Calcium parameter none exceeded the limit and was below the desirable limits of 75 mg/l as well.
8. The highest change detected for the parameter pH was in 2011-2018 and lowest change detected was in year 2011-2017 just before the highest change occurred (Table-3.3 & Fig-11)

Table 3.3 Highest & Lowest Change Detection of pH

Year	Parameter	Range (Highest)	Range (Lowest)
2011-2012	pH	0.549972	-0.399786
2011-2013	pH	0.0499001	-0.34981
2011-2014	pH	0.199989	-0.249872
2011-2015	pH	0.199941	-0.209785
2011-2016	pH	0.419974	-0.169788
2011-2017	pH	0.199773	-0.699955

2011-2018	pH	0.599957	-0.169183
2011-2019	pH	0.0399761	-0.349851
2011-2020	pH	0.159904	-0.379839
2011-2021	pH	0.0497761	-0.409842

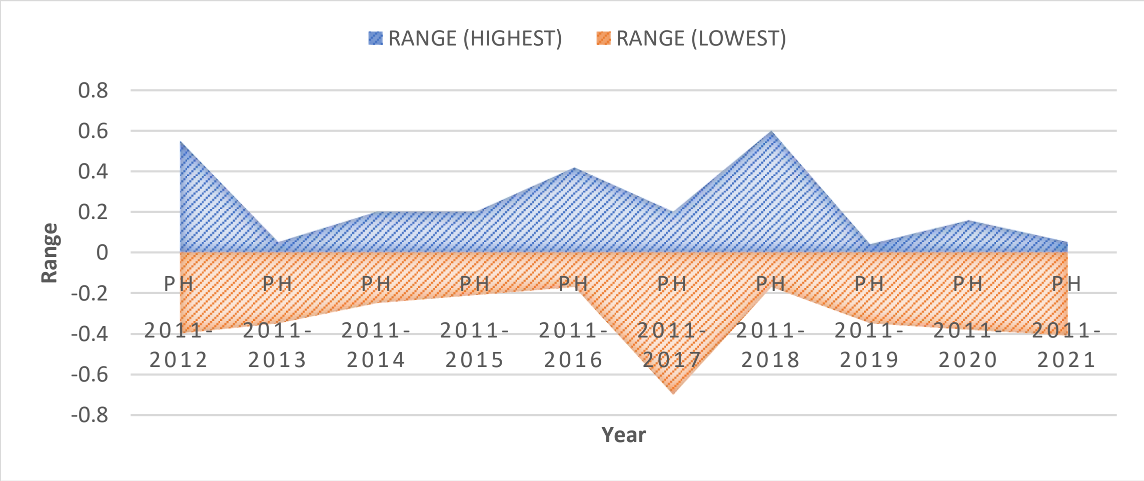

Fig- 11- Graph of the highest & lowest change detected for parameter pH for each cumulative year

9. The highest change detected for the parameter EC was in 2011-2018 and lowest change detected was in year 2011-2017 just before the highest change occurred (Table-3.4 & Fig-12).

Table 3.4: Highest & Lowest Change Detection of EC

Year	Parameter (in µmhos/cm)	Range (Highest)	Range (Lowest)
2011-2012	EC	199.917	-183.945
2011-2013	EC	292.931	-63.9392
2011-2014	EC	309.827	-223.915
2011-2015	EC	245.88	-144.431
2011-2016	EC	237.896	-168.976
2011-2017	EC	257.894	-147.915
2011-2018	EC	347.84	-215.884
2011-2019	EC	399.833	-138.979
2011-2020	EC	373.825	-152.981
2011-2021	EC	443.781	-254.899

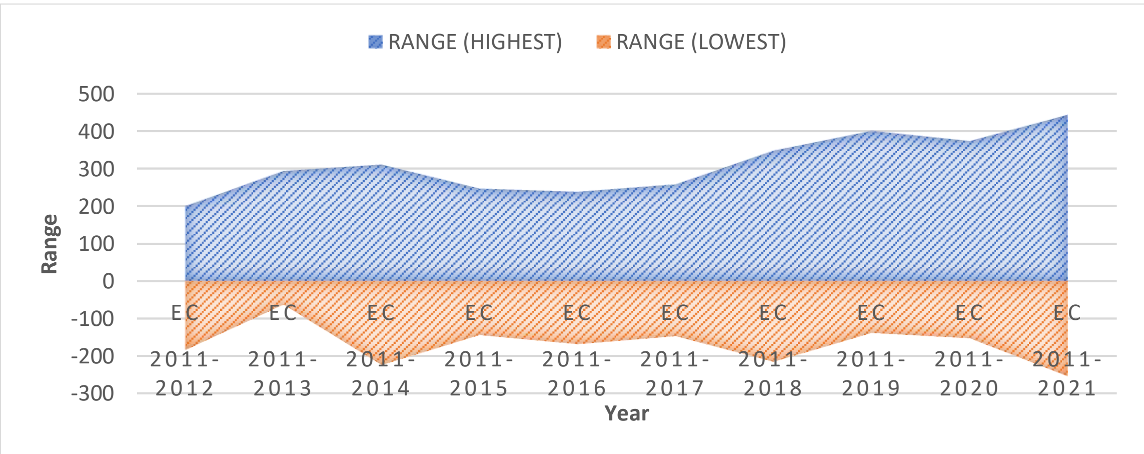

Fig- 12- Graph of the highest & lowest change detected for parameter EC for each cumulative year

10. The highest change detected for the parameter Calcium was in 2011-2018 and lowest change detected was in year 2011-2017 just before the highest change occurred (Table-3.5 & Fig-13).

Table 3.5: Highest & Lowest Change Detection of Ca^{2+}

Year	Parameter (mg/L)	Range (Highest)	Range (Lowest)
2011-2012	Ca	-2.0007	-27.999
2011-2013	Ca	31.9991	-19.9856
2011-2014	Ca	35.9839	-15.9932
2011-2015	Ca	31.9883	-13.9909
2011-2016	Ca	36.1282	-15.9572
2011-2017	Ca	27.9989	-19.9896
2011-2018	Ca	36.1456	-23.9725
2011-2019	Ca	23.9913	-15.9901
2011-2020	Ca	23.9989	-15.9917
2011-2021	Ca	27.9857	-19.998

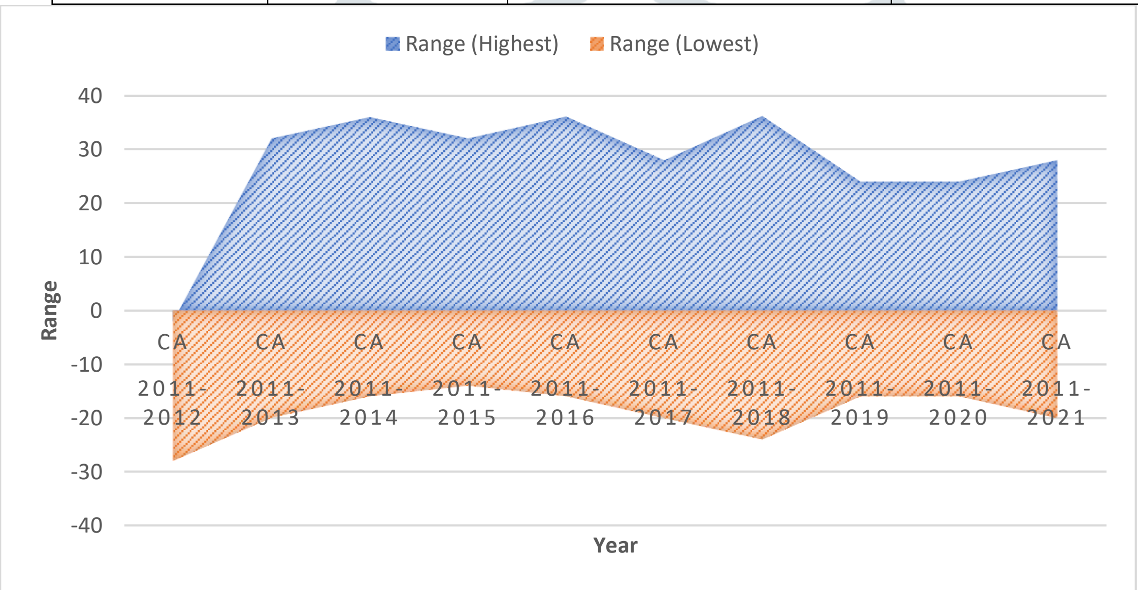

Fig- 13- Graph of the highest & lowest change detected for parameter Ca^{2+} for each cumulative year

IV. Conclusion:

1. The study of Lucknow district of 8 blocks illustrated that from lowest to highest the average pH, EC & Calcium ranged from 7.80 to 8.28, 421.27 to 823.81 in mg/l & 17.55 to 58.83 in mg/l respectively.
2. The two blocks namely Bakshi-ka-talab & Chinhat for parameter pH are gradually moving beyond the permissible limits. Bakshi-ka-Talab showed gradual ups & downs while surpassing the permissible limit of 8.5 twice in the year 2016 and 2018.
3. Spatial distribution of human health at risk is mapped by integrating water quality data with urban population density data. It has been observed that the urban populations in and around the Trans-Gomti area would be the potential "hot spot" for health hazards. As a result, some measures are necessary to prevent anthropogenic contamination of groundwater in these areas. For the parameter EC 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.
4. The parameter Calcium none exceeded the limit and was below the desirable limit. The change detection was performed to locate areas that have changed in magnitude or direction, usually over a period. Highest change found for parameters were in year; 2011-2018, 2011-2021, 2011-2018; for pH, EC, & Ca respectively.
5. Lucknow district's groundwater contamination needs significant remediation. The initiatives can ensure that water will remain drinkable for a long time.

V. Acknowledgement:

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