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An Integrated Remote Sensing & GIS Techniques Based Approach to Study Spatial Distribution of Parameters Controlling Groundwater Contamination in Parbhani Tehsil of Maharashtra State, India

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Abstract:
The present study attempts to decode the subsurface water contamination with compare to seasonal variations in hydro-geochemistry of groundwater in the Parbhani tehsil of Maharashtra, India. The study area is situated around Parbhani city is a part of Godawari-Purna sub basin located between 76^{0}36′ to 77^{0}59′ E and 19^{0}07′ to 19^{0}17′N. A total of 88 groundwater samples of post-monsoon (POMS) and pre-monsoon (PRMS) seasons were collected and analyzed for major ion composition such as viz.pH, Ec, TDS, CO_3, HCO_3, Ca, Mg, Cl, Na, K, NO_3, F andSO_4 using standard analytical procedures of APHA. The finding of study is digitized using ArcGIS software, ERDAS imaging software, Landsat images along with survey of India's official toposheet. As compared to the WHO drinking standards, majority of groundwater samples are fit for drinking. Nonetheless, its noticed that the higher concentration bicarbonate in subsurface water was found in upper catchment of the watershed in pre and post monsoon season on the other hand traces of fluoride contamination has been found in central part of study area. The subsurface water bodies situated near Parbhani, Raipur and Balsa villages shows the concentration of calcium, magnesium, sodium and potassium above permissible limit possibly due to exceed use of fertilization for cultivation besides urbanization in the study area.

Keywords: *Groundwater, water pollution, ArcGIS, Parbhani Tehsil, Maharashtra*

INTRODUCTION

Groundwater is a vital component of the water cycle and constitutes a key portion of the water cycle. The demand for fresh water has increased rapidly due to population growth and intensive agricultural activities (Gaikwad et al., 2022; Chavhan et al., 2022). Subsurface water has become a major source of water for the domestic, industrial and agricultural sectors of many countries. It is estimated that approximately one-third of the world's population use groundwater for drinking (Hojjati-Najafabadi et. al., 2022; UNEP, 1999). At the national level nearly 60% of all districts have problems related to either the quantitative availability or quality of groundwater or both

(Wanget al., 2022; Wodeyar et al., 1998). The availability of freshwater is evolving as a serious threat to the living community throughout the world due to rapid industrialization, urbanization, and rising population (Nourani et al., 2022; Jayasiri et al., 2022; Patil et al., 2020; Mishra et al., 2021).The quality of water and its suitability for human consumption can be determined by examining its physicochemical characteristics (Dutt et al., 2022).

Hydro-geochemical study is a common part for most of the hydrogeological studies. In any hydrogeological project, evaluation of groundwater quality is of equal importance due to the utility of water for agriculture. The degradation of groundwater quality by natural and/or anthropogenic pollutants is threatening the ecosystem and even lives of future generation (Elango et. al., 2018; Solangi et. al., 2019; Bouwer, 2000). Groundwater is clearly the preferred source for farmers. However, India's groundwater lifeline is in precarious situation. To illustrate, at the national level that nearly 60% of all districts in India have problems related to either the quantitative availability or quality of groundwater or both. Inferior quality of groundwater with high salinity, fluoride and nitrate contents limits the availability of fresh water. Industrial and urban pollution has caused to deterioration in quality of ground water. It is a major source of drinking water, besides it is an important source for agriculture sector. Compared to surface water, groundwater offers better insurance against drought because of the long lag between changes in recharge and response to groundwater levels.

Groundwater is the most important natural resource. Over three fourths of food grain production from the irrigated lands, is contributed from lands irrigated by groundwater. With every passing day, our dependence on ground water is increasing and is likely to remain dominant. Groundwater is clearly the preferred source by the farmers.(Mazinder Baruah et al., 2022; Naik et al., 2022; Sharma et al., 2021; Bowes et al., 2020; Wagh et al., 2018)Hydro-geochemical studies are a common part of most of hydrogeological studies. In any hydrogeological project, the evaluation of groundwater quality is of equal importance as the other studies, because the utility of water for various purposes like domestic, drinking, agriculture and industries depend on its quality aspects. The prominent stream namely Pingalgarh nala flows as a main drain line. About 44 open wells were demarcated in the watershed area using GPS. Ground water samples were collected in plastic sampling bottles thoroughly cleaned and sterilized. The ground water samples were collected with the help of rope and bucket from the identified wells.Hydro-geochemical study was conducted in Parbhani cluster of Maharashtra state for groundwater quality assessment with respect to its suitability for irrigation as well as for domestic use. Based on the hydro-geochemical study and analysis of various parameters, ground water contaminated sites were identified using Remote Sensing and GIS techniques. High concentration of calcium, magnesium, sodium and potassium in groundwater was found near to Parbhani city and in Balsa and Raipur villages both in pre and post monsoon in shallow and deep aquifers indicating that the stagnated sewage water percolated in the ground water and causes the groundwater contamination and thus ground water from Raipur and Balsa villages were not suitable for drinking and irrigating the crop. The fluoride concentration in groundwater was found to be higher in central part of watershed but within the permissible limit. Chemical analysis of water is not a recent aspect; it has been a routine for more than a century. However, the relation between the geologic and hydrologic environment and the chemistry of water, which is a science of 'Hydro-geochemistry', is a subject of more recent development and research. Hydro-geochemical studies are a common part of most of hydrogeological studies. In any hydrogeological project, the evaluation of groundwater quality is of equal importance as the other studies, because the utility of water for various purposes like domestic, drinking, agriculture and industries depend on its quality aspects. The high concentration of calcium, magnesium, sodium and potassium in groundwater is found near to Parbhani city and in Balsa and Raipur villages both in pre and post monsoon in

shallow and deep aquifers indicating that the stagnated sewage water percolated in the ground water and causes the groundwater contamination and thus ground water from Raipur and Balsa villages were not suitable for drinking and irrigating the crop.

STUDY AREA

The Parbhani area of Maharashtra State is part of Godawari-Purna Sub basin located between $76^0$36' to $77^0$59' E and $19^0$07' to $19^0$17'N. The study area is of 34413.87 ha. Fig. 1(A). Most of the area is under cultivation with no forest. The domestic sewage water from Parbhani city and nearby area led to main stream flowing from the area which is passing through most of the cultivated land wherein number of bore wells and open wells are located. The sewage water stagnates in an area at various locations and thus percolates in the ground which has resulted in groundwater contamination.

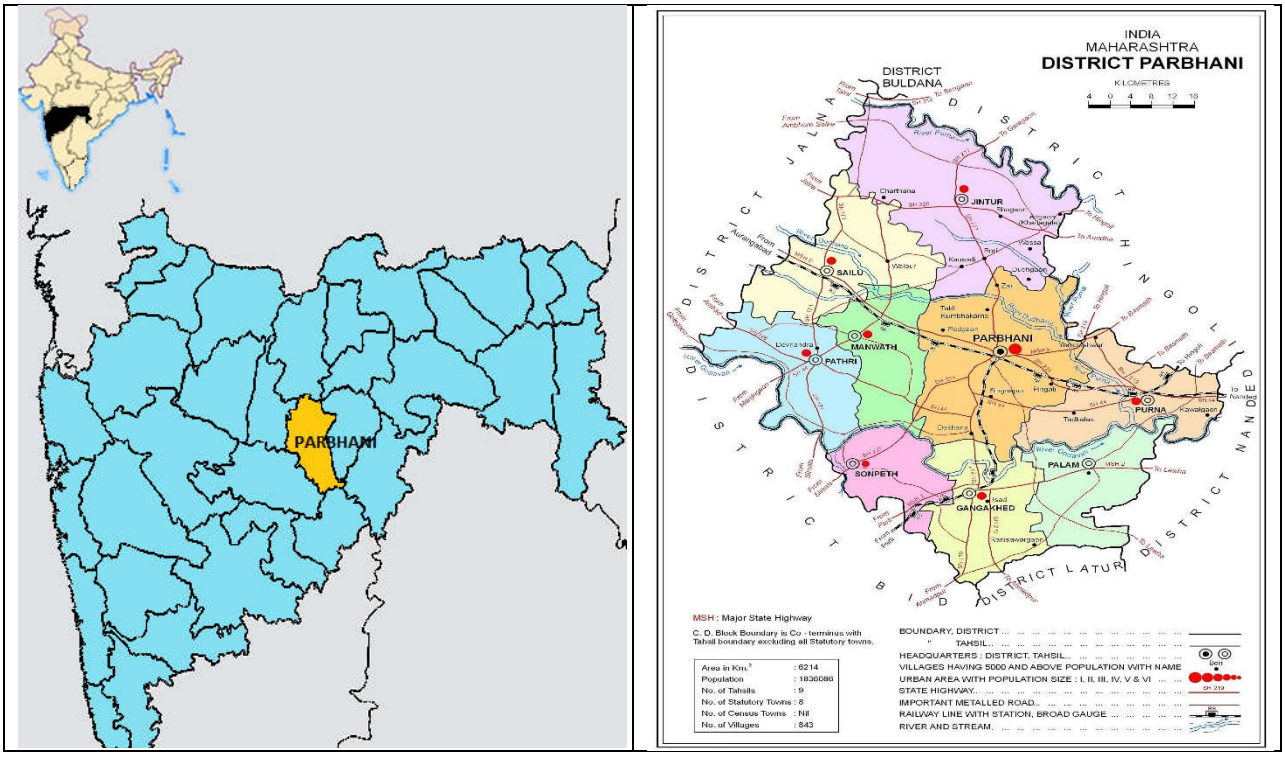

Figure 1(A): Administrative Map of Parbhani District of Maharashtra (Source: Census 2011)

METHODOLOGY

The 44 open wells and 44 bore wells located at various locations in the watershed area near Parbhani were selected and the positions of selected wells i.e. latitude and longitude were recorded using GPS instrument and accordingly the locations of selected wells were marked on satellite delineated image as presented in fig. 1(B).

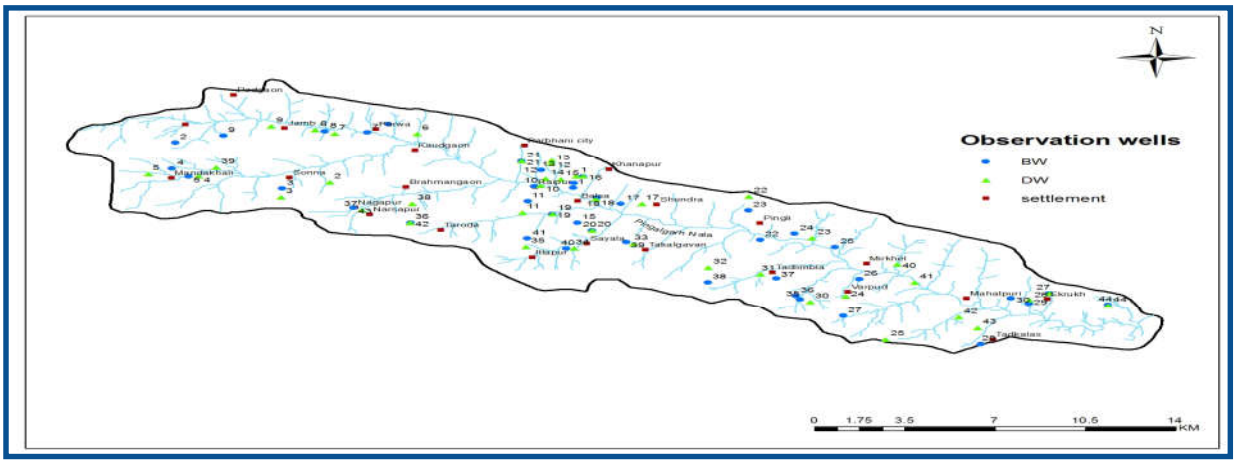

Figure 1(B): Satellite delineated image with locations of observation wells

The water samples both in pre and post monsoon season were collected from all the monitored wells. Ground water samples were collected using plastic sampling bottles thoroughly cleaned and sterilized. The ground water samples were collected with the help of rope and bucket from the identified wells. The water surface was disturbed a little to remove any floating material before collection of samples. Water samples for its quality assessment are analysed with respect to chemical constituents. The water samples were analyzed in the Groundwater testing laboratory of State Government located in Bori of Parbhani district for determination of concentrations of various components viz. pH, Ec, TDS, CO_3, HCO_3, Ca, Mg, Cl, Na, K, NO_3, F and SO_4. Seasonal evaluation of hydro-geochemical parameters using correlation and regression analysis was conducted by following standard procedure (Janardhana, et. al., 2015). An attempt was also made to study the local variation of concentration of various chemical constituents of ground water using Arc GIS software.

The SOI toposheet (1:50000 scale) and LANDSAT image (1977) of the study area were collected from Regional Remote Sensing Centre-Central, NRSC, ISRO, Nagpur. The scientific data was procured from National Remote Sensing Centre,(NRSC) ISRO, Hyderabad. ERDAS IMAGINE software was used for satellite data processing, geo-referencing, Digital image processing and interpretation of thematic maps. In 2008, Sadashivaiah implemented the ARC GIS 10.3.1 to conducted hydro-geochemical analysis and evaluation of groundwater quality in Tumkur Taluka of Karnataka State, India. Similar procedure was followed in hydro-geochemical analysis in the present study. Software package was used for generating the GIS database of thematic layer for preparation of map of various concentrations.

RESULTS

The data on hydro-geochemical analysis with its maximum and minimum value of concentrations under dug wells and bore wells are presented in Table 1 and Table 2.

Table 1: Basic statistical parameters for different chemical variables of groundwater inParbhani area during pre-monsoon-2019

Variables	Maximum		Minimum		Mean		Standard deviation		% Coefficient of Variance	
	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well
Ca	537.07	384.76	8.016	10.02	123.67	122.5	94.44	68.69	76.36	56.07
Mg	347.63	287.72	24.31	27.60	103.30	109.8	57.22	50.52	55.39	45.99
Na	234.50	254.10	9.00	9.00	50.76	54.10	54.07	56.71	106.5	104.8
K	28.00	28.00	3.00	3.00	7.73	8.20	5.09	5.17	65.85	63.05
HCO_3	646.81	702.8	48.81	65.20	340.19	363.3	137.9	138.9	40.54	38.24
CO_3	72.011	78.61	12.00	12.00	31.28	38.43	15.08	16.83	48.21	43.79
Cl	1389.6	1125.8	127.6	137.4	312.98	299.8	252.6	214.5	80.74	71.55
SO_4	455.65	468.15	200.3	211.4	309.55	326.5	71.90	75.73	23.23	23.19
Fe	1.189	1.189	0.063	0.063	0.22	0.24	0.22	0.22	100	91.67
TDS	840	880	285	285	584.93	588.0	124.3	140.8	21.26	23.95
EC	4.56	4.87	0.68	0.67	1.37	1.35	0.92	0.87	67.15	64.44
pH	8.46	8.99	6.35	6.67	7.66	7.89	0.41	0.54	05.35	06.84

Note: all values are in PPM except EC, Ec:dSm^{-1}

Table 2: Basic statistical parameters for different chemical variables of ground water in Parbhani area during post- monsoon-2019

Variables	Maximum		Minimum		Mean		Standard deviation		%coefficient of Variance	
	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well	Dug well	Bore well
Ca	237.87	189.7	8.10	10.02	71.78	74.57	43.34	32.98	60.38	44.23
Mg	148.6	148.89	13.75	20.3	48.44	64.02	27.06	24.37	55.86	38.07
Na	134.5	150.1	9.00	10.00	34.08	38.56	29.08	31.55	85.33	81.82
K	28	19.00	3.00	3.00	7.73	7.61	5.09	4.01	65.85	52.69
HCO_3	345.75	402.99	25.45	58.2	184.14	210.23	76.03	78.61	41.29	37.39
CO_3	32.89	58.56	10.01	10.58	17.55	26.68	6.95	11.07	39.60	41.49
Cl	689.68	625.05	67.6	78.65	160.25	181.37	128.30	124.17	80.06	68.46
SO_4	255.6	298.15	95.39	142.00	161.31	203.02	38.06	46.72	23.59	23.01
Fe	1.021	0.236	0.042	0.046	0.14	0.13	0.19	0.04	135.71	30.77
TDS	485	690	138	208	308.29	346.98	96.10	105.32	31.17	30.35
EC	2.52	2.82	0.39	0.41	0.90	0.91	0.36	0.48	40	52.75
pH	7.64	7.74	6.45	7.01	7.13	7.27	0.20	0.21	02.80	02.89

Note: all values are in PPM except EC

The data presented in tables indicated that the concentrations of Ca, Mg, Na and K are found to be more in the pre monsoon season as compared to post monsoon season. The concentration of Ca and Mg are more than permissible limit in some area which are reflected in the maps. Similarly, the concentration of carbonate and bicarbonate is also found to be more in pre monsoon season as compared to post monsoon season. The concentration of chlorine is also found to be more than permissible limit. The reason is that all domestic sewage water released from Parbhani city contains mostly domestic sewage water normally containing caustic soda. As no waste water from any industry is released to the stream, the concentration of Fe and other heavy metals is low. The GIS generated maps show the specific locations where the concentrations of different parameters are high and where the reclamation is required. The various thematic maps of different concentrations are shown in Fig 2 to Fig 9. High concentration of calcium, magnesium, sodium and potassium in ground water was found near to Parbhani city and in Balsa and Raipur villages both in pre and post monsoon in shallow and deep aquifers indicating that the stagnated sewage water percolated in the ground water and causes the groundwater contamination and thus ground water from Raipur and Balsa villages were not suitable for drinking and irrigating the crop. However, in rest of the area of watershed, the groundwater was found to be safe with respect to cations concentration and found to be suitable for irrigating the crop. In case of shallow aquifer, in pre monsoon season, the concentration of carbonate in groundwater was found to be higher in central southern part of watershed covering the villages Taroda, Itlapur, Sayala and Takalgavan. However, in post monsoon season, the carbonate concentration in ground water was found to be higher in Itlapur village region and in rest of the area of watershed, the carbonate concentration in groundwater was found to be low and within safe limit. In case of deep aquifers, both in pre and post monsoon season, the carbonate concentration in ground water was found to be higher in Jamb and Parwa villages located in northern part of the watershed also in Narsapur, Nagapur, Itlapur and Varpud villages and towards the confluent part of the watershed.

The bicarbonate concentration in groundwater was found to be higher in upper catchment of the watershed both in shallow and deep aquifers in pre and post monsoon season particularly in Mandakhali, Jamb, Sonna, Parwa, Nagapur, Narsapur and Brahmangaon villages. However in central to lower part of watershed, the bicarbonate concentration of ground water were found to be low to medium in both the aquifers. Similarly, chlorine concentrations were also found to be high nearer to Parbhani city indicated that the domestic waste water left into the Pingalgarh *nala* mainly percolates to the ground water aquifer zones nearer to the *nala* located near to Parbhani city. The aquifer zones farther away from the *nala* are presently safe, but the increase in the quantity of the domestic waste may lead to contamination of the aquifers farther away from the *nala* in the future. Hence this is an important inference for future management of domestic waste from Parbhani city. The fluoride concentration in groundwater was found to be higher in central part of watershed but within the permissible limit.

Chatterjee et. al., 2010 conducted ground water quality assessment in Dhanbad district of Jharkhand and found higher concentration of some chemicals and concluded that some groundwater sources are not suitable for irrigation as well as for domestic use. Patil (2011) tested groundwater quality in open and bore wells around Amalner town of Jalgaon district and found higher concentration of calcium and magnesium in some of the locations due to polluted water, hence not found suitable for irrigating crops. The present study was conducted following the similar procedure and results confirms with the similar trend.

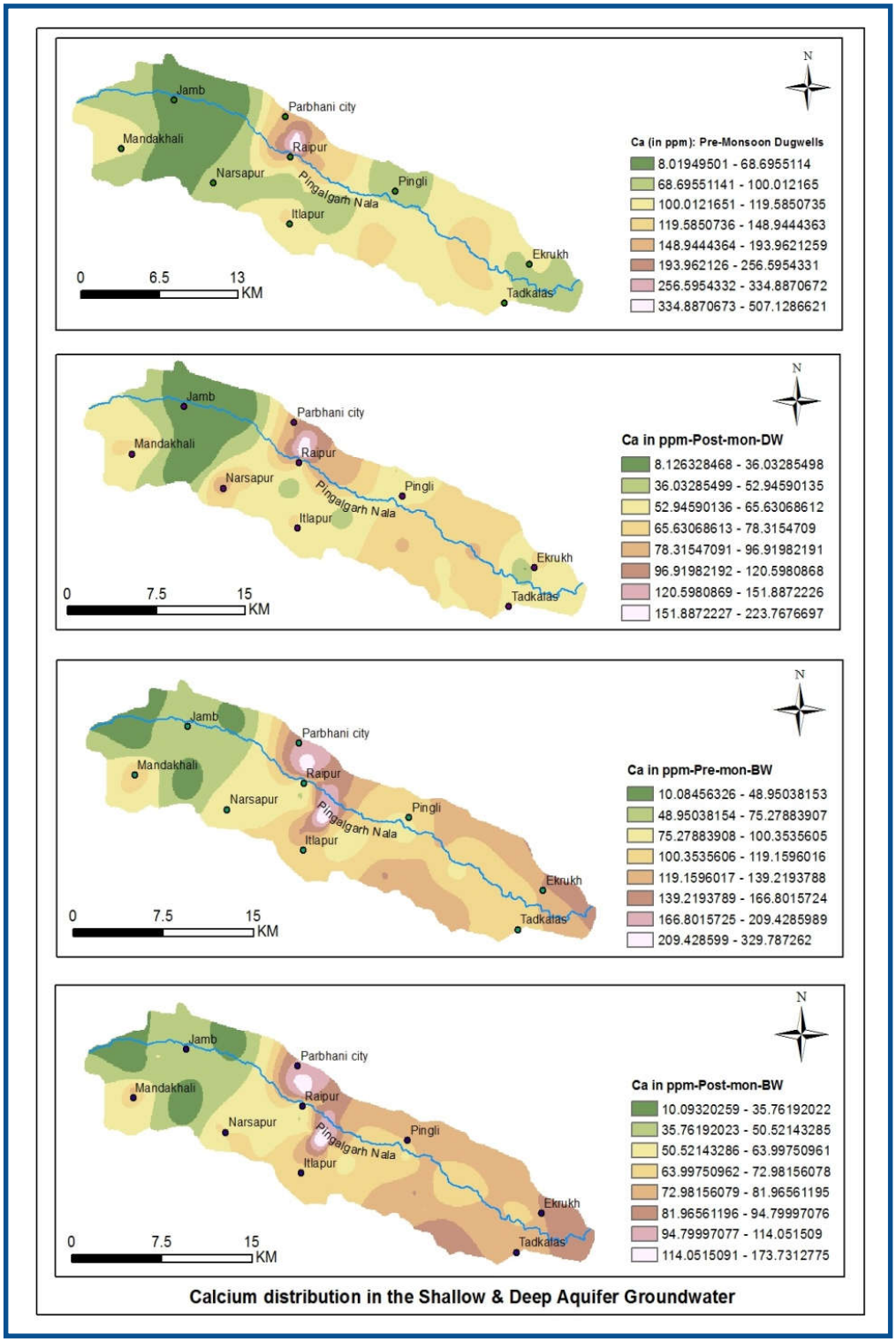

Figure 2: Calcium distribution in the study area

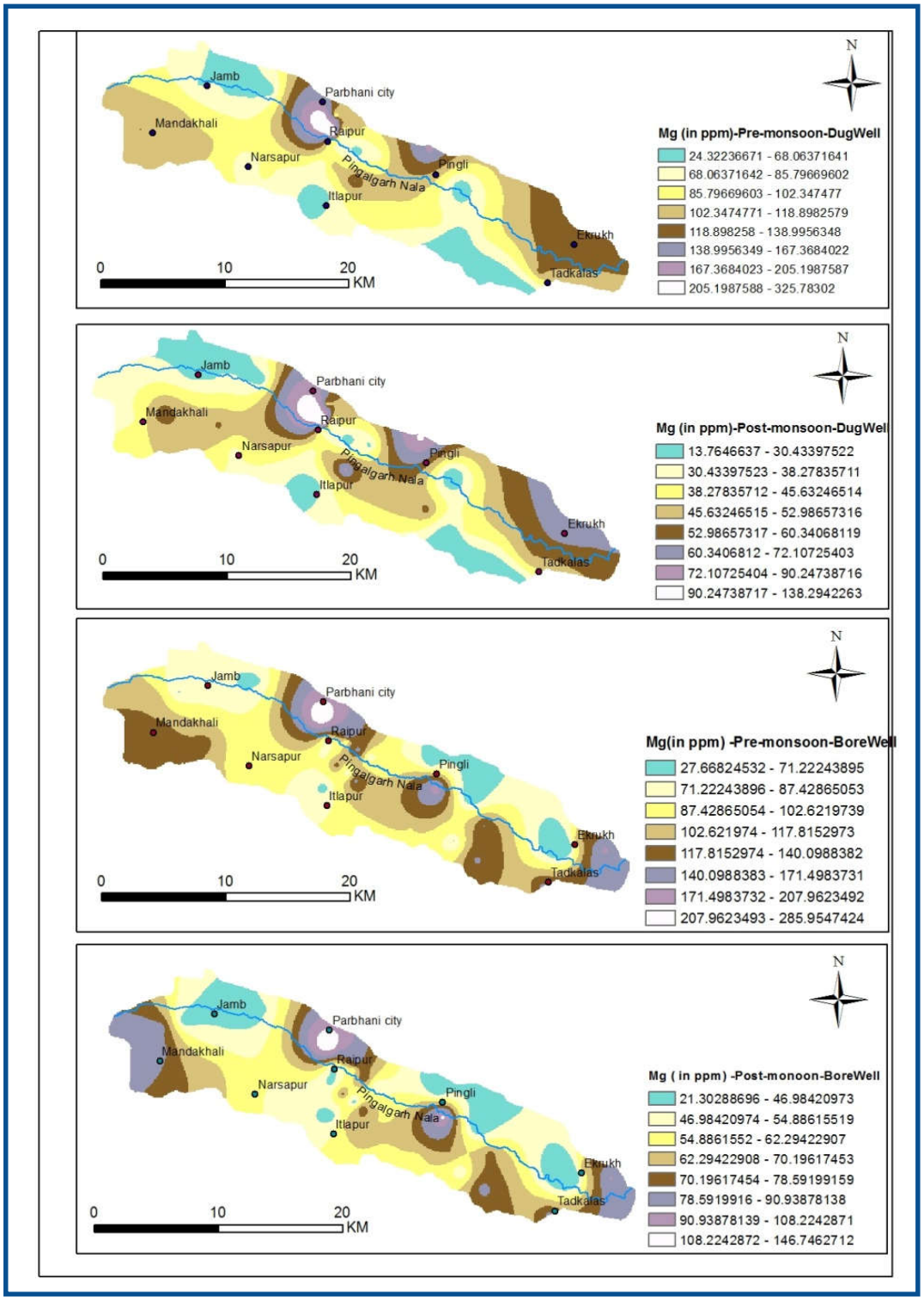

Figure 3: Magnesium distribution in the study area

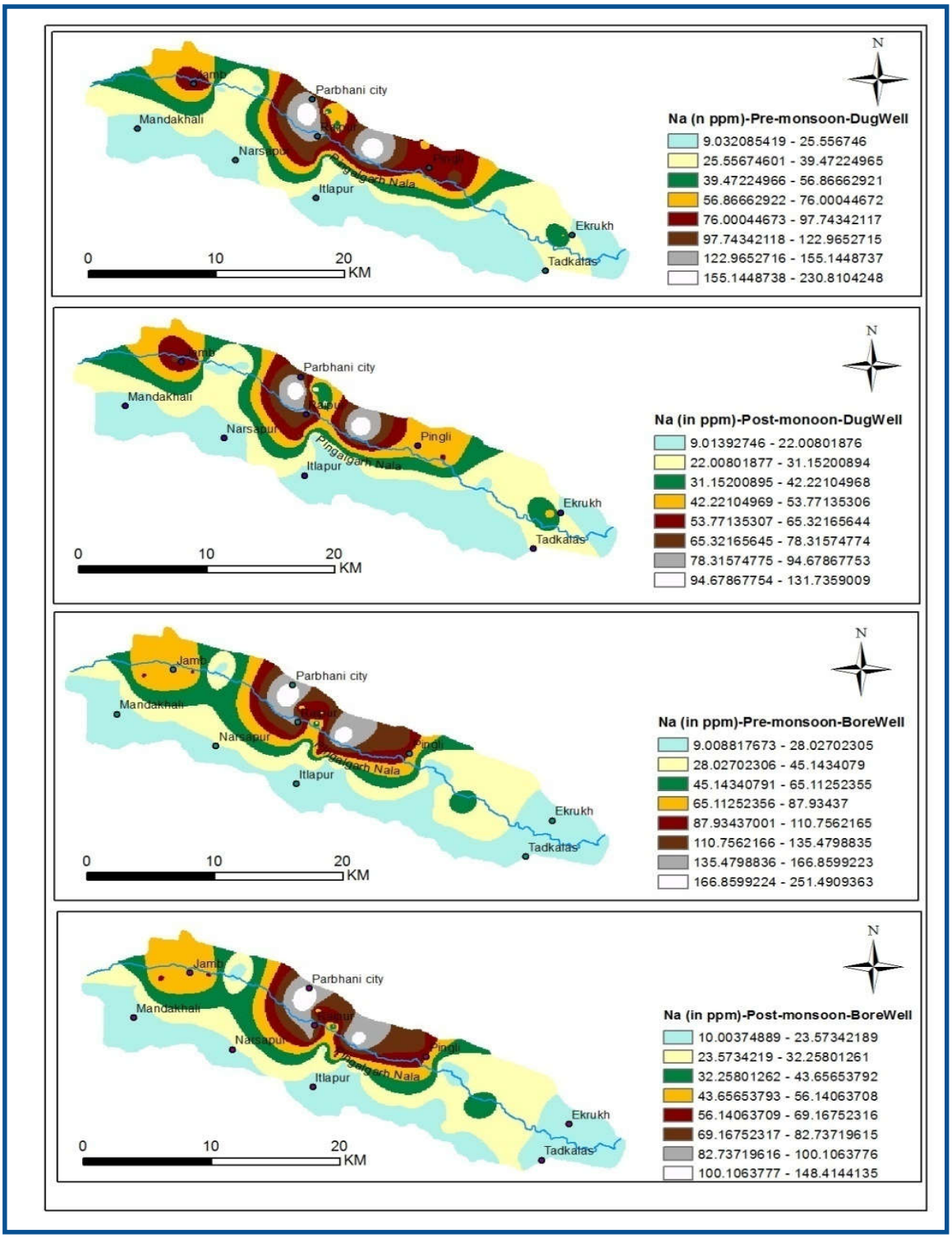

Figure 4: Sodium distribution in the study area

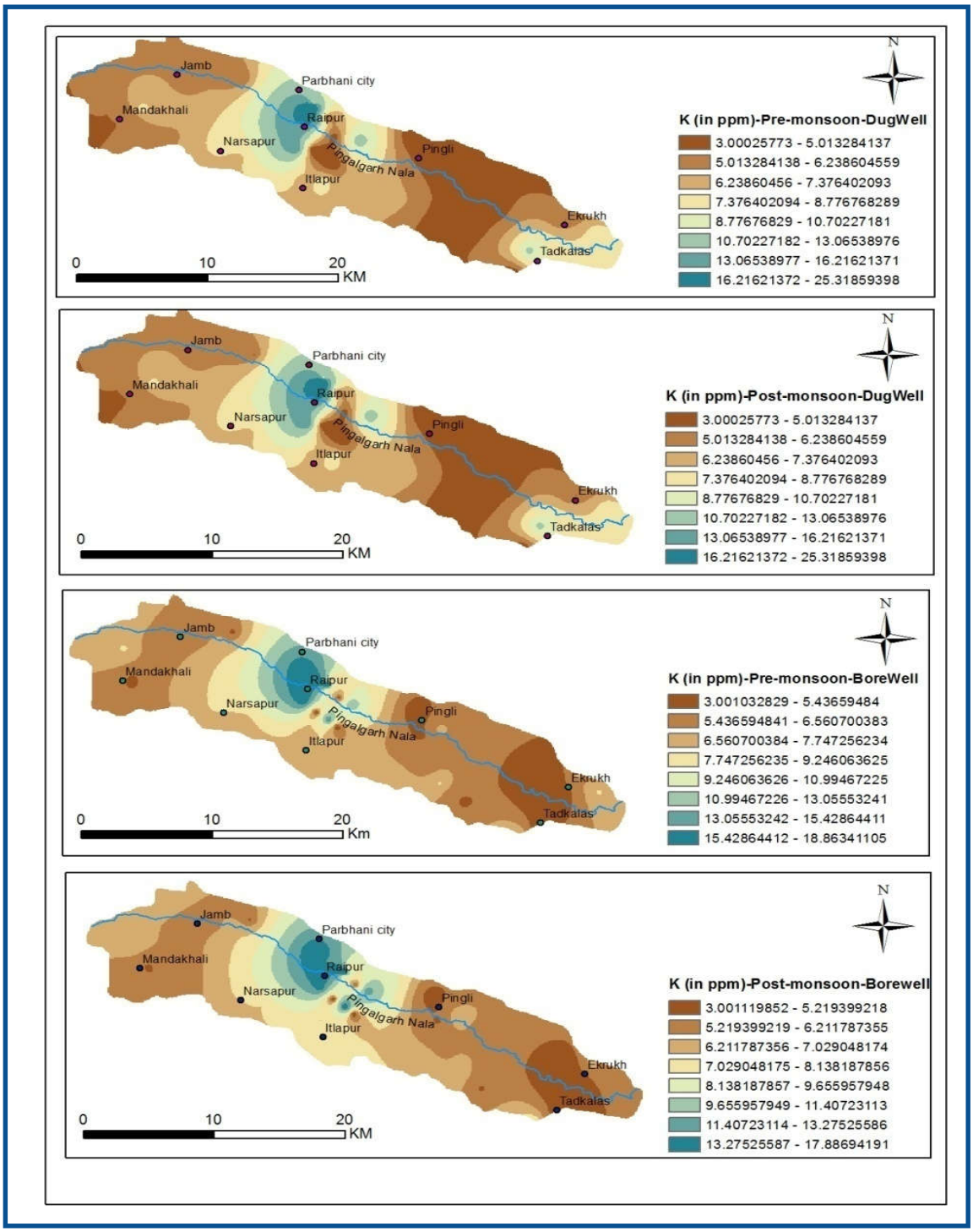

Figure 5: Potassium distribution in the study area

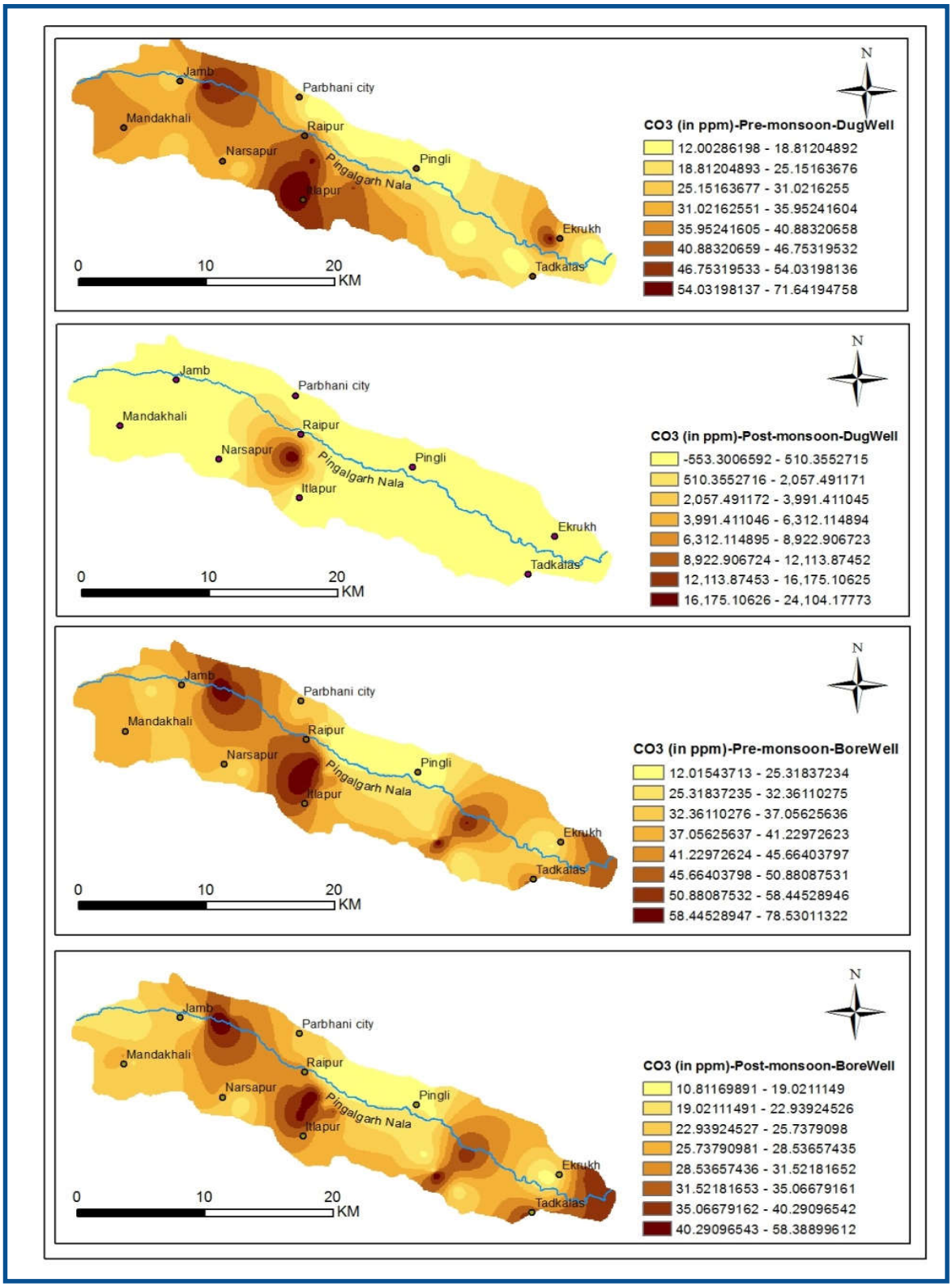

Figure 6: Carbonate distribution in the study area

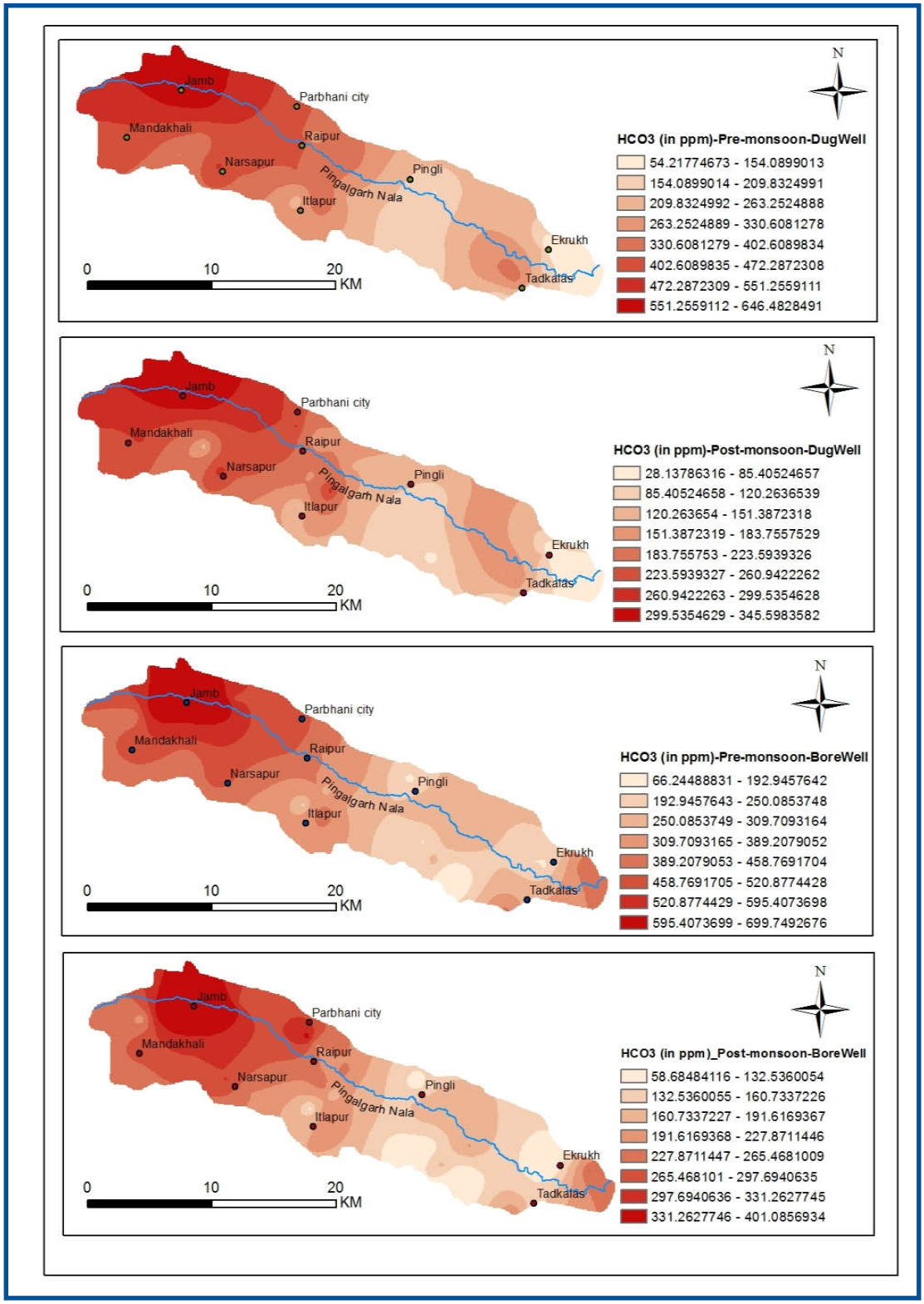

Figure 7: Bicarbonate distribution in the study area

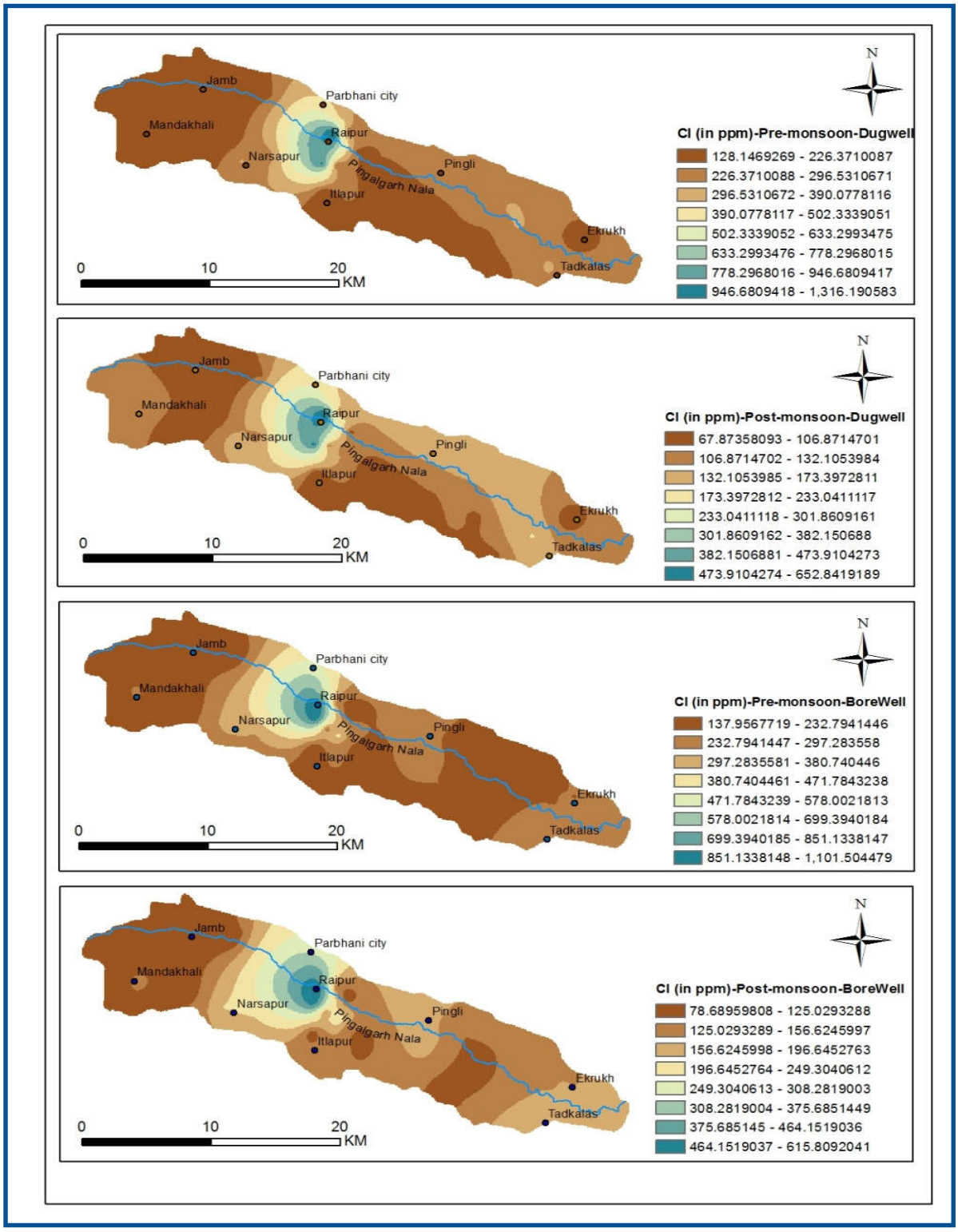

Figure 8: Chlorine distribution in the study area

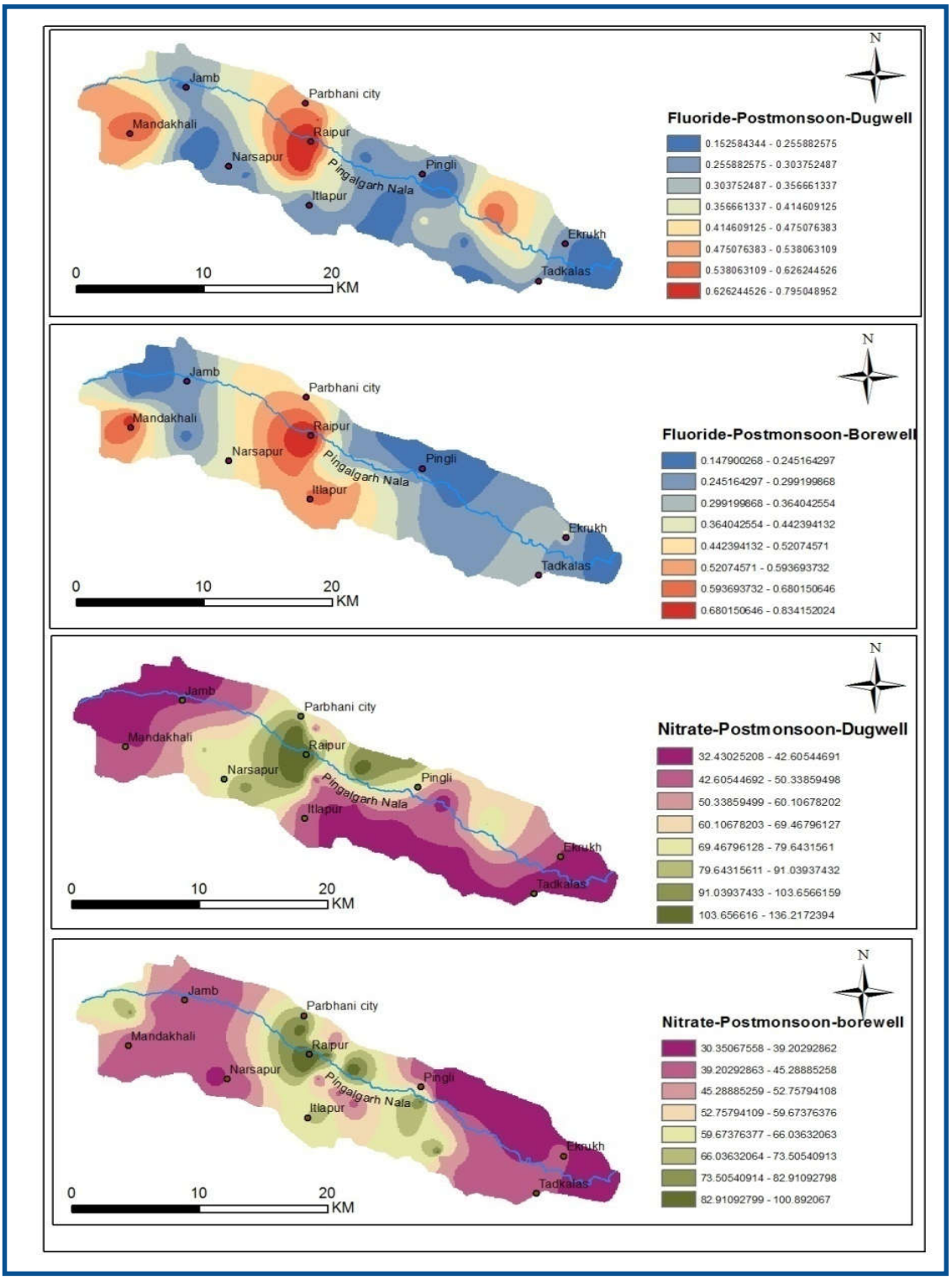

Figure 9: Fluoride distribution in the study area

CONCLUSIONS

The High concentration of calcium, magnesium, sodium and potassium in ground water was found near to Parbhani city and in Balsa and Raipur villages both in pre and post monsoon in shallow and deep aquifers. The carbonate concentration in groundwater was found higher in Jamb and Parwa villages located in northern part of the watershed also in Narsapur, Nagapur, Itlapur and Varpud villages and towards the confluent part of the watershed. The bicarbonate concentration in groundwater was found to be higher in upper catchment of the watershed both in shallow and deep aquifers in pre and post monsoon season particularly in Mandakhali, Jamb, Sonna, Parwa, Nagapur, Narsapur and Brahmangaon villages. The fluoride concentration in groundwater was found to be higher in central part of watershed but within the permissible limit. Based on concentrations of various parameters, the groundwater contaminated area is identified wherein the precautionary measures will have to be taken for further use of water for irrigating crops and for domestic use.

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