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Quality Characterization of Groundwater in Biwan Watershed of the Mewat District, Haryana, India

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ABSTRACT: *Groundwater is the major source for drinking and irrigation in rural areas of arid and semi-arid regions of India. India being a rapidly growing country in Asia is facing both groundwater quantity and quality problems. Mewat region generally include the Mewat District of Haryana and parts of Alwar, Bharatpur, and Dholpur districts of Rajasthan. Mewat is considered as one of the least economically and socially developed regions in the country. The presence of poor quality natural resources like soil and water may be one of the reasons behind the backwardness of Mewat district of Haryana. Keeping in view, a study was carried out to find out the groundwater quality status of Biwan watershed located in the Mewat district of Haryana in 2012-13. Sixty groundwater samples from tubewells with their GPS co-ordinates were collected on random basis from Tapkan, Biwan, Shonkh, Palla and Palladi villages of Biwan watershed during pre-monsoon period i.e. May, 2012. Tube wells selected for the study were mostly used for irrigation. Samples were analyzed for different irrigation quality parameters such as EC, pH, sodium (Na^+), calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3^{2-}), bicarbonate (HCO_3^-) by the standard methods. Spatial variability maps of groundwater quality parameters such as pH, EC, residual sodium carbonate (RSC) and sodium adsorption ratio (SAR) were also prepared using ArcGIS-9.0 software at Water Technology Centre, IARI, New Delhi. Analytical results indicated that higher percentage (> 90%) of poor quality water samples were found in Palladi and the least was in Palla village. In whole watershed, 45%, 50% and 5% groundwater samples were found in quality conditions of good, saline and alkali, respectively. As per spatial variability maps, the higher salinity (ECw > 4 dS/m) area was observed in some part of the villages Tapkan, Biwan, Shonkh, Palla and Palldi whereas lower salinity area or maximum good quality groundwater area was found in part of Palla village of Biwan watershed. This information will be helped for further water resource management and planning.*

Keywords: *Groundwater, Mewat, Salinity, Watershed, Water Quality.*

INTRODUCTION

The demand of freshwater is being tremendously increasing at global level (Raju *et al*., 2010). Groundwater is the major source of freshwater which fulfill the need of water for drinking and domestic, industrial, and irrigation uses in many parts of the world as well as arid- and semi-arid regions of India (Raju and Reddy, 2007). Due to rapid growth in population, urbanization and industrialization, intense agricultural activities and inadequate supply of surface waters, dependency on groundwater resource has increased tremendously in recent years (Kumar *et al*., 2006). Hence, Innumerable large towns, villages and many cities in India derive water supply from groundwater for different uses through municipality network and also from large number of private boreholes (Raju *et al*., 2009). According to the Falkenmark Water Stress Indicator (Falkenmark *et al*., 1989), a country or region is said to experience "water stress" when annual water supplies drop below 1700 m^3/person/year. At levels between 1700 and 1000 m^3/person/year, periodic or limited water shortages can be expected. When a country is below 1000 m^3/person/year, the country then faces water scarcity. In India, per capita availability of surface water in the years 1991 and 2001 were 2309 m^3 and 1902 m^3. However, it has been projected that per capita surface water availability is likely to be reduced

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to 1401 m^3 and 1191 m^3 by the years 2025 and 2050, respectively. The Per capita water availability in the year 2010 was 1588 m^3 against 5200 m^3 of the year 1951 in the country (CWC, 2011). Hence, India is water stressed country today and is likely to be water shortage country by 2050. Unfortunately, the water quality in 32-83% with an average of approximately 45% of the aquifers surveyed in different states of the country has been observed to be poor in quality (Minhas and Gupta, 1992). Therefore, India being a rapidly growing country in Asia is facing both groundwater quantity and quality problems. Mewat is a historical region of Haryana and Rajasthan states in northwestern India. The loose boundaries of Mewat region are not precisely determined but generally include Mewat District of Haryana and parts of Alwar, Bharatpur, and Dholpur districts of Rajasthan.

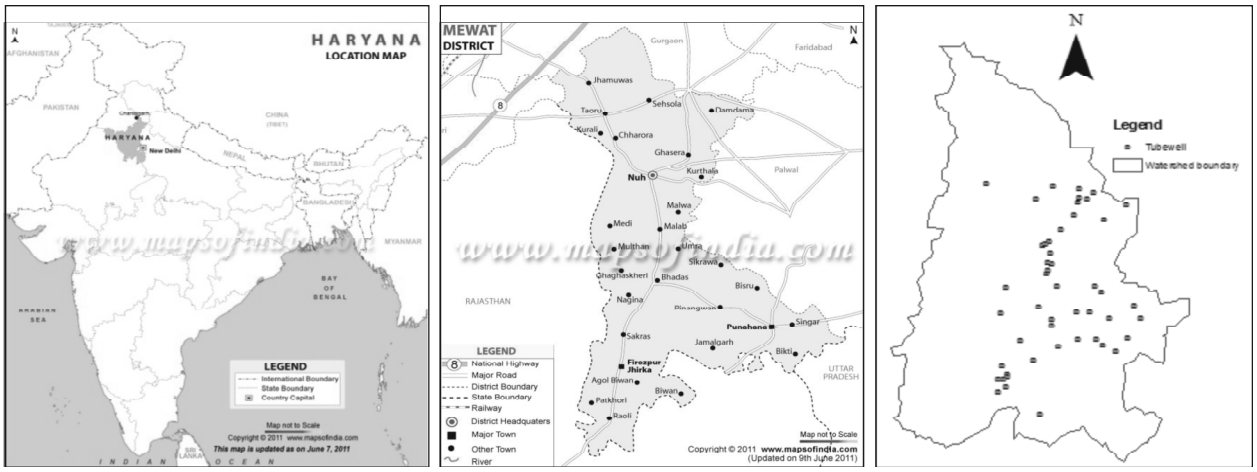
Mewat district is one of the 21 districts of Haryana state in northern India. The district was created as the 20th district of Haryana from erstwhile Gurgaon and the Hathin Block of Faridabad districts on 4 April 2005. However, Hathin sub-division was moved to the new district of Palwal in 2008. It is bounded by Gurgaon district on the north, Rewari district on the west and Faridabad and Palwal districts on the east. Now it consists of five sub-division or blocks, namely, Taoru, Nuh, Nagina, Ferozpur Jhirkha and Punhana. Nuh is the headquarters town of this district, which occupies an area of 1,859.61 square kilometres and as of the 2011 India census had a population of 10,89,406. Mewat is predominantly populated by the Meos, who are agriculturalists along with Hindus. Mewat is considered as one of the least economically and socially developed regions in the country (Aggarwal, 2004). The presence of poor quality natural resources like soil and water may be possible reasons behind the backwardness of Mewat district of Haryana. Keeping in view, the Biwan watershed located in Nuh block of Mewat district in Haryana was selected for present study.

MATERIALS AND METHODS

General Characteristics of Study Area

The study area was selected as Biwan watershed located in Nuh block of Mewat district in Haryana, India (Fig. 1). There is no major industry (except mining) in Mewat district, and about 62% of its population lives below poverty line (Kaur *et al*., 2009). As compared to the literacy rate of Haryana state in general (75.55%), the literacy rate of Mewat is just 54.08%. Of this, the female literacy rate is a mere 36.60% (Census of India, 2011). Biwan watershed, comprises the Tapkan, Biwan, Shonkh, Palla and Palladi villages, lies between 27°39′ and 28° 20′ North latitude and 76°51′ and 77°20′ East longitudes. The major soil texture classes of the area are loamy sand, sandy loam and sandy.

The Biwan watershed is also socio-economically backward. Agriculture, the base economic activity of the people is deprived of irrigation. The ground water is the major source of water in the district area as well as in Biwan watershed. There is no river and area is drained by artificial drains namely Nuh,



(a) (b) (c)

Figure 1: Maps showing location of study area in (a) India (b) Mewat district (c) Biwan watershed boundary with groundwater sampling points.

Ujina and Kotla drains. They carry rain water into Yamuna river. The climate of Biwan watershed is semi arid and annual rainfall is about 594 mm. About 80% of this rainfall is received during July-September months. The cropping seasons are *kharif* (June-September) and *rabi* (October-March). No major crops were cultivated during the summer season (April-May). The principal crops grown during *kharif* and *rabi* seasons are pearl millet/sorghum/bottle gourd and wheat/mustard/tomato, respectively. These are primarily irrigated with tube well water.

Groundwater Sampling and Analysis

Groundwater samples with their GPS co-ordinates were collected in 500 ml labeled plastic bottles from 60 tubewell situated in Tapkan, Biwan, Shonkh, Palla and Palladi villages of Biwan watershed during pre-monsoon season (May, 2012). Prior to the sample collection, each plastic bottle was rinsed with the water sample to be collected for at least five to six times. The irrigation water quality parameters such as EC, pH, sodium, calcium, magnesium (Jackson, 1973; APHA, 1995), carbonate, bicarbonate (Richards, 1954) were analyzed as per the standard procedures at Water Technology Centre, IARI, New Delhi. The concentrations of sodium, calcium, magnesium, carbonate and bicarbonate so determined were transformed to Sodium Absorption Ratio (SAR) and Residual Sodium Carbonate (RSC), as proposed by Eaton (1950), concentrations (Ayers and Westcot, 1985). These together with EC values were then used for assessing the overall quality of the test water samples as per water quality classification given by Central Soil Salinity Research Institute (CSSRI) Karnal. CSSRI classification of the groundwater quality is given in Table 1.

Table 1
Groundwater quality classification for irrigation (ICAR-CSSRI, Karnal)

Class	*Quality Group*	*EC (dS/m)*	*SAR*	*RSC (me L^{-1})*
A.	Good Quality Water	< 2	< 10	< 2.5
B.	Saline Water			
	(i) Marginal saline	2-4	< 10	< 2.5
	(ii) Saline	> 4	< 10	< 2.5
	(iii) High SAR saline	> 4	> 10	< 2.5
C.	Alkali Water			
	(i) Marginal alkali	< 4	< 10	2.5-4.0
	(ii) Alkali	< 4	< 10	> 4.0
	(iii) Highly alkali	Variable	> 10	> 4

GIS Mapping and Geo-spatial Analysis

For assessment of spatial variability in groundwater quality of the study area, the GPS recorded sample site co-ordinates (*i.e.*, latitudes and longitudes) were imported (as a point feature theme layer) in Arc-GIS 9.0 software. Spatial variability maps of EC, pH, SAR and RSC were prepared using kriging geospatial techniques (Franke, 1982).

RESULTS AND DISCUSSION

The village-wise description on groundwater quality and its spatial variability in Biwan watershed is described as below :

Table 2
Groundwater quality of Tapkan village

	Tube well Location									
Sr. No.	*Latitude*	*Longitude*	*pH*	*EC (dS/m)*	*Na^+ (me/L)*	*$Ca^{2+} + Mg^{2+}$ (me/L)*	*$CO_3^{2-} + HCO_3^-$ (me/L)*	*RSC*	*SAR*	*Groundwater Quality Group (CSSRI, Karnal)*
1.	28°08.857′	76°58.995′	7.54	1.45	6.2	7.6	2	–5.6	3.18	Good Quality
2.	28°08.970′	76°59.119′	7.95	1.64	7.2	6.6	3.4	–3.2	3.96	Good Quality
3.	28°08.999′	76°59.151′	7.93	3.25	16	14.2	2.4	–11.8	6.00	Marginal Saline
4.	28°09.027′	76°59.149′	8.09	2.55	13	10.2	2.4	–7.8	5.76	Marginal Saline
5.	28°09.013′	76°59.189′	7.82	4.01	13	27.4	2	–25.4	3.51	Saline
6.	28°08.836′	76°59.343′	7.92	2.88	11.5	15.6	2.4	–13.2	4.12	Marginal Saline
7.	28°08.788′	76°59.428′	7.98	4.29	19.5	24	2.6	–21.4	5.63	Saline
8.	28°08.779′	76°59.494′	7.95	4.89	32	19.6	2.2	–17.4	10.22	High SAR Saline
9.	28°08.784′	76°59.402′	7.97	4.13	17.5	25.6	1.8	–23.8	4.89	Saline
10	28°08.585′	76°59.144′	8.14	1.62	2.5	13	1.6	–11.4	0.98	Good Quality
11	28°08.503′	76°59.105′	8.21	0.86	2.4	6.6	2.4	–4.2	1.32	Good Quality
12.	28°08.505′	76°59.028′	8.37	0.84	3.2	5.2	2	–3.2	1.98	Good Quality
13.	28°08.591′	76°58.997′	8.39	0.72	1.7	5.6	3.8	–1.8	1.02	Good Quality
14.	28°08.426′	76°59.028′	8.71	0.82	5	4.4	3.6	–0.8	3.37	Good Quality

Table 3
Groundwater quality of Biwan village

	Tube well Location									
Sr. No.	*Latitude*	*Longitude*	*pH*	*EC (dS/m)*	Na^+ *(me/L)*	$Ca^{2+} + Mg^{2+}$ *(me/L)*	$CO_3^{2-} + HCO_3^-$ *(me/L)*	*RSC*	*SAR*	*Groundwater Quality Group (CSSRI, Karnal)*
1.	28° 08.165′	076° 58.792′	8.43	0.73	2	5.8	3.2	–2.6	1.17	Good Quality
2.	28° 08.136′	076° 58.937′	8.24	2.15	10.5	7.0	1.0	–6	5.61	Marginal Saline
3.	28° 08.346′	076° 59.056′	8.53	0.90	5	3.6	6.4	2.8	3.73	Marginal Alkali
4.	28° 08.317′	076° 59.205′	8.37	1.83	8.5	9.2	2.2	–7	3.96	Good Quality
5.	28° 08.232′	076° 59.198′	8.16	3.59	19	8.0	2.4	–4.6	9.50	Marginal Saline
6.	28° 08.175′	076° 59.196′	8.30	2.01	11	9.4	3.6	–5.8	5.07	Marginal Saline
7.	28° 08.129′	076° 59.185′	8.32	3.44	14	17.8	2.6	–15.2	4.69	Marginal Saline
8.	28° 08.234′	076° 59.102′	7.93	3.56	13	20.4	2.0	–18.4	4.07	Marginal Saline
9.	28° 08.228′	076° 59.031′	8.58	1.09	5	4.0	2.2	–1.8	3.54	Good Quality
10	28° 08.236′	076° 58.869′	8.39	0.73	2.3	4.4	2.6	–1.8	1.55	Good Quality
11	28° 08.266′	076° 58.952′	8.44	0.91	6.5	3.2	3.6	0.4	5.14	Good Quality
12.	28° 08.001′	076° 58.994′	8.03	3.88	24	22.4	1.4	–21	7.17	Marginal Saline
13.	28° 08.001′	076° 59.140′	8.06	4.43	23.5	24.2	2.2	–22	6.76	Saline

Tapkan Village

It is evident from Table 2 that 50% groundwater samples were good in quality and rest 50% had salinity from marginal saline to high SAR saline. The presence of salinity in groundwater may be due to excessive pumping for intensification of agriculture by using excessive amount of fertilizers. The groundwater quality also depends on the chemistry of water in the recharge area as well as the different geochemical processes that are occurring in the subsurface and responsible for the seasonal and spatial variations in groundwater chemistry (Matthess, 1982).

Biwan Village

It is clear from Table 3 that more than 60% groundwater of Biwan village was poor in quality due to presence of higher salinity and alkalinity. The higher salinity in the groundwater of Biwan village was due to its location near to discharge zone. Generally, groundwater at the discharge zones tend to have higher mineral concentration compared to that at the recharge zones due to the longer residence time and prolonged contact with the aquifer matrix (Freeze and Cherry, 1979).

Shonkh Village

The groundwater quality of Shonkh village is given in Table 4 which indicates that more than 60% groundwater of Shonkh village was poor in quality due to higher salinity. The higher salinity in the groundwater of Shonkh village was may be due to presence of saline aquifer and topographic variations. It is supported by Toth (1984) and stated that groundwater salinity may evolve by interacting with aquifer minerals or internal mixing among different

Table 4
Groundwater quality of Shonkh village

	Tube well Location									
Sr. No.	*Latitude*	*Longitude*	*pH*	*EC (dS/m)*	Na^+ *(me/L)*	$Ca^{2+} + Mg^{2+}$ *(me/L)*	$CO_3^{2-} + HCO_3^-$ *(me/L)*	*RSC*	*SAR*	*Groundwater Quality Group (CSSRI, Karnal)*
1.	28° 07.778′	76° 58.903′	8.16	2.46	11.5	13.4	3.8	–9.6	4.44	Marginal Saline
2.	28° 07.755′	76° 58.867′	8.23	2.57	11	17.2	2	–15.2	3.75	Marginal Saline
3.	28° 07.751′	76° 58.849′	8.27	1.36	6.0	7.4	1.8	–5.6	3.12	Good Quality
4.	28° 07.774′	76° 58.830′	8.28	2.49	12	12.4	2.2	–10.2	4.82	Marginal Saline
5.	28° 07.747′	76° 59.003′	7.89	6.6	30	53.6	1.4	–52.2	5.80	Saline
6.	28° 07.760′	76° 59.047′	7.92	5.03	23	34.4	2.6	–31.8	5.55	Saline
7.	28° 07.795′	76° 58.992′	8.30	2.78	13.5	11.2	3.2	–8	5.70	Marginal Saline
8.	28° 07.606′	76° 58.893′	8.44	1.28	7.0	5.6	2.4	–3.2	4.18	Good Quality
9.	28° 07.336′	76° 59.322′	8.82	4.29	33	9.8	6.6	–3.2	14.91	HighSAR saline
10.	28° 07.410′	76° 59.496′	8.81	1.90	12.8	6.6	5.0	–1.6	7.05	Good Quality
11.	28° 07.392′	76° 59.394′	8.8	1.98	12.5	6.6	6.8	0.2	6.88	Good Quality

Table 5
Groundwater quality of Palla village

	Tube well Location									
Sr. No.	*Latitude*	*Longitude*	*pH*	*EC (dS/m)*	*Na^+ (me/L)*	*$Ca^{2+} + Mg^{2+}$ (me/L)*	*$CO_3^{2-} + HCO_3^-$ (me/L)*	*RSC*	*SAR*	*Groundwater Quality Group (CSSRI, Karnal)*
1.	28°06.813′	76°59.488′	8.41	4.39	20	23.6	3	–20.6	5.82	Saline
2.	28°07.306′	76°58.987′	7.56	1.43	3.5	10.6	2.8	–7.8	1.52	Good Quality
3.	28°07.303′	76°58.914′	8.09	1.09	2	8.4	2	–6.4	0.98	Good Quality
4.	28°07.251′	76°58.864′	8.33	1.19	2.5	8.6	2.8	–5.8	1.21	Good Quality
5.	28°07.124′	76°58.860′	8.50	0.85	2.5	5.2	3.8	–1.4	1.55	Good Quality
6.	28°07.147′	76°58.860′	8.61	0.53	1.7	4.2	4.6	0.4	1.17	Good Quality
7.	28°07.012′	76°58.875′	8.55	0.60	2.3	7.4	3.2	–4.2	1.20	Good Quality
8.	28°06.968′	76°58.861′	8.61	0.52	1.6	4	3.6	–0.4	1.13	Good Quality
9.	28°07.139′	76°58.606′	8.56	0.49	1.3	4	4.2	0.2	0.92	Good Quality
10	28°07.095′	76°58.609′	8.44	0.50	1.4	4.2	3.8	–0.4	0.97	Good Quality
11	28°07.280′	76°58.692′	8.08	3.20	11	26.6	2.2	–24.4	3.02	Marginal Saline
12.	28°07.450′	76°58.746′	8.51	0.48	3	4.4	3	–1.4	2.02	Good Quality
13.	28°07.493′	76°58.742′	7.96	4.24	13	33.8	1.4	–32.4	3.16	Saline

groundwater along-flow paths in the subsurface. Schuh *et al*. (1997) indicated that increases in solute concentrations in the groundwater were caused by spatially variable recharge, governed by micro-topographic controls.

Palla Village

The groundwater quality of Palla village is depicted in Table 5. It is evident from Table 5 that more than 75% of groundwater of Palla village was found good in quality. The availability of good quality groundwater in the Palla village may be due to its location near to high gradient below Aravali foot hills. At the foot hills, the soil is sandy and highly permeable and state government had constructed several check dams over there. However, groundwater gets recharged with rain water. This village was recognized as good quality water pocket of the Biwan cluster of watersheds.

Palladi Village

It is evident from Table 6 that more than 90% of groundwater of Palladi village was poor in quality due to presence of higher salinity and alkalinity. The presence of salinity and alkalinity in the groundwater of Palladi village may be due to the presence of saline/alkaline aquifer, higher salinity and sodicity in soils and excessive pumping. The higher EC is mainly attributed to geochemical processes and higher mineralization prevailing in this village. As the electrical conductivity is temperature dependent, its variability in a given water sample depends on the concentration and types of inorganic ions present (Hem, 1985).

Quality Classification of Groundwater of Biwan Cluster of Watersheds as Whole

As per the CSSRI (Karnal) guidelines for grouping of the poor quality groundwater for irrigation, the quality of all groundwater samples were characterized

Table 6
Groundwater quality of Palladi village

	Tube well Location									
Sr. No.	*Latitude*	*Longitude*	*pH*	*EC (dS/m)*	*Na^+ (me/L)*	*$Ca^{2+} + Mg^{2+}$ (me/L)*	*$CO_3^{2-} + HCO_3^-$ (me/L)*	*RSC*	*SAR*	*Groundwater Quality Group (CSSRI, Karnal)*
1.	28°06.648′	76°58.410′	7.93	3.24	12.5	20.6	1.6	–19	3.89	Marginal Saline
2.	28°06.535′	76°58.407′	8.25	1.78	9.5	9.2	4	–5.2	4.43	Good Quality
3.	28°06.542′	76°58.463′	8.17	2.17	11	9.4	3.2	–6.2	5.07	Marginal Saline
4.	28°06.486′	76°58.462′	8.37	2.22	12	10.2	3.4	–6.8	5.31	Marginal Saline
5.	28°06.435′	76°58.401′	8.21	4.5	26	23.6	3.6	–20	7.57	Saline
6.	28°06.495′	76°58.385′	8.15	2.7	11	15.2	3.2	–12	3.99	Marginal Saline
7.	28°06.480′	76°58.416′	8.86	2.41	15	6.6	9.5	2.9	8.26	Marginal Alkali
8.	28°06.651′	76°58.860′	8.19	4.11	22	16.8	2.2	–14.6	7.59	Saline
9.	28°06.707′	76°58.748′	8.55	1.26	8	4.2	6.8	2.6	5.39	Marginal Alkali

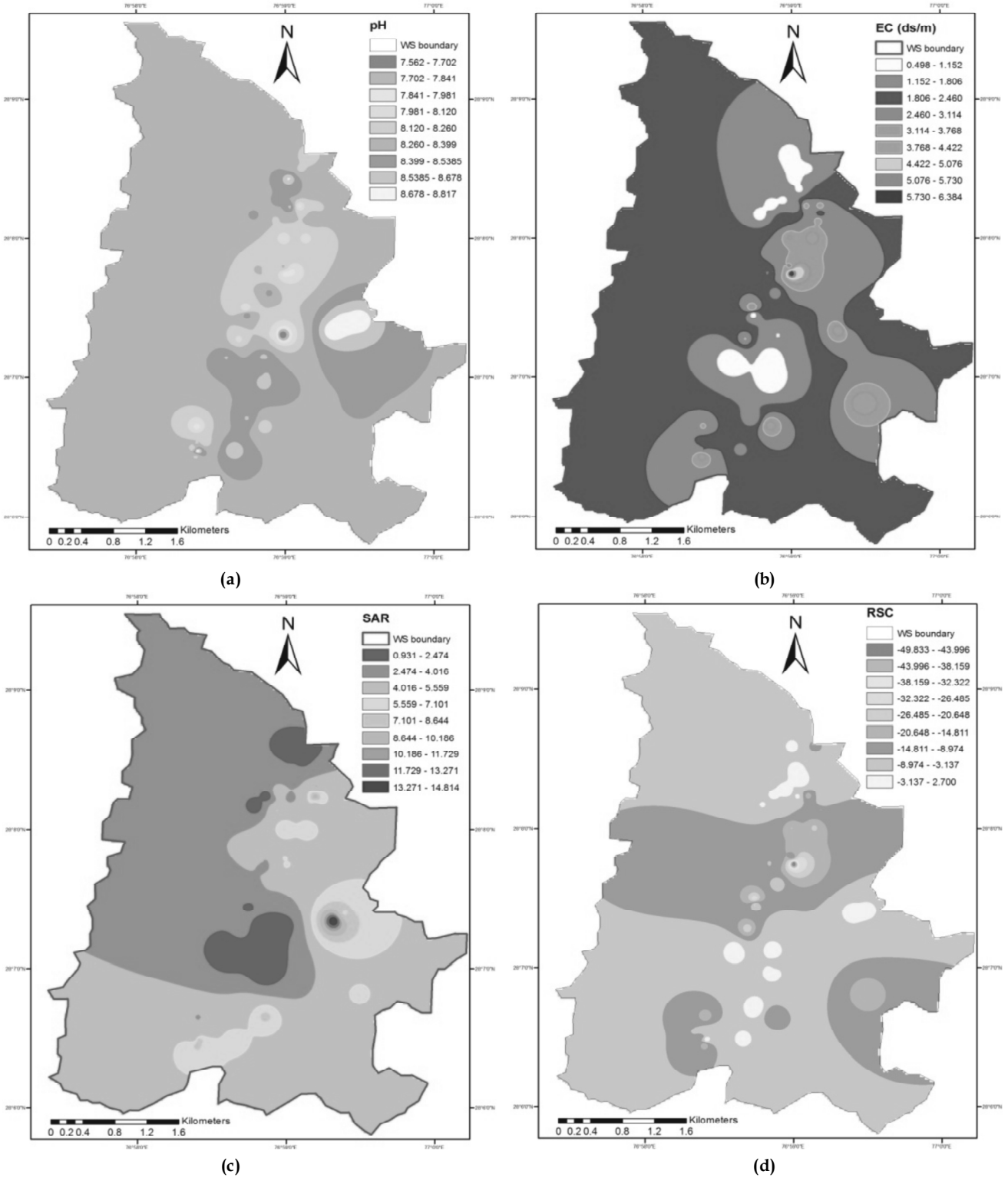


Figure 3: Spatial variability maps of (a) pH, (b) EC, (c) SAR and (d) RSC

into different groups and classes that are given in Fig. 1. Groundwater samples of good quality (45%), marginal saline (30%), saline (17%), high SAR saline (3%) and marginal alkali (5%) were found in the study area (Fig. 1a). Based on ABC class of water quality, 45%, 50% and 5% samples were found as class-A (good quality water), Class-B (saline water) and class-C (alkali water), respectively (Fig 1b).

Spatial Variability of Groundwater Quality in Biwan Watershed

The spatial variability maps of groundwater quality parameters such as pH, EC, RSC and SAR were constructed using ArcGIS-9.0 software and are given in Fig 2 (a-d). It is evident from Fig 2a that the pH of the groundwater in the study area lies in the alkaline range (pH > 7). The higher pH was observed in some parts of Palla, Palladi and Shonkh village. Higher salinity (EC > 3 dS/m) was of found in some part of the villages Tapkan, Biwan, Shonkh, Palla and Palladi (Fig 2b). Maximum area under good quality groundwater was found in Palla villages of Biwan watershed. The high SAR (>10) area was found in some parts of Shonkh village (Fig 2c) whereas higher RSC (>2.5 meq/L) problem was found in the area of Palladi village (Fig 2d).

CONCLUSION

The study revealed that more than 50 per cent of groundwater samples of Biwan watershed of Mewat, Haryana were poor in quality due to higher salinity. Higher salinity in groundwater was mainly due to geochemical processes, mineral rock-water interaction and higher mineralization in aquifers. The salinity in groundwater was also spatially variable in the Biwan watershed. Stringent monitoring and control measures in the areas of low groundwater quality are necessary to ensure sustainable safe use of the resource. Emphasis on recharging the groundwater aquifers in the rainy seasons may be much helpful for improving the groundwater quality.

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