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Assessment and characterization of underground irrigation water of paddy and sugarcane growing areas in Navsari district of Gujarat

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Abstract
The present study was carried out to assess and categorize the quality of the underground water of village Butlaw and Dabhalia in Navsari district of Gujarat. It was found that the pH of water samples was neutral to alkaline in nature ranged from 7.25 to 7.81 and 7.17 to 7.67 during pre and post-monsoon seasons with the mean values of 7.50 and 7.39 respectively. EC values of groundwater during the pre-monsoon season was found ranged from 0.84 to 1.31 dS m^{-1} with a mean value of 1.01 dS m^{-1} while during the post-monsoon season it was found ranged from 0.77 to 1.22 dS m^{-1} with a mean value of 0.92 dS m^{-1}. From the salinity point of view, all the water samples were classified as high-salinity water (C3) groups. The pre-monsoon season SAR values were found ranged from 1.39 to 3.82 with a mean value of 2.77 whereas in the case of post-monsoon season SAR was found ranged from 1.27 to 3.74 with a mean value of 2.62. In terms of sodium hazard, all the water samples were classified as low-sodium water (S1) groups. A highly significant positive correlation of SAR was found with the RSC during both the seasons (r=0.600** and r=0.592**). Due to the presence of salinity hazards in the groundwater, it will be better to use surface water for irrigation purposes. If there is less availability of surface water, irrigation with groundwater should be done after ensuring well drainage facilities in the fields.

Keywords: Groundwater, Navsari, RSC, salinity, SAR, sodium hazard

Introduction
Water is one of the most important inputs required for crop production. India accounts for 2.2% of the global land and 4% of the world's water resources and accommodates 16% of the world's population (Ramesh and Elango, 2011) [4]. Supplementary irrigation is important in India where one-third of the land surface falls under arid and semi-arid climate and the rainfall is seasonal and erratic. The total groundwater potential in India is estimated at 43.1 M ha-m and the utilizable groundwater for irrigation is assessed as 32.47 M ha-m. It is likely to increase to 35 M ha-m by 2025 (Minhas, 2000) [3]. Groundwater will continue to be used intensively, in spite of decreasing the land area of irrigated production, as a consequence of physical depletion, low quality water, economic depletion, water logging and salinization (Datta, 2005) [1]. Majority of the underground tube-well waters contain a high concentration of salts and their continuous use for irrigation adversely affects soil health and agricultural production. It necessitates continuous monitoring of groundwater for assessing the possible damage on salinity and alkalinity induced soil health. Though the selected villages are endowed with canal irrigation facilities, yet farmers are compelled to use groundwater in some parts owing to the higher elevation of their fields than canal heads. The farmers are also using groundwater for irrigation in the event of prolonged dry spell particularly at critical growth stages of the crop during monsoon season. Therefore, the present study was planned to assess the quality and categorize the groundwater of village Butlaw and Dabhalia in Navsari district of Gujarat based on various parameters viz. pH, EC (Electrical conductivity), RSC (Residual Sodium Carbonate), SAR (Sodium Adsorption Ratio).

Materials and Methods
Study area
Gujarat is situated on the west coast of India and lies between $20^0$01' and $24^0$00' North latitude and $68^0$04' and $74^0$04' East longitude. Navsari district is located between $20^0$07' and $21^0$00' North latitude and $72^0$43' and $73^0$00' East longitude. The district is located in the south-eastern part of Gujarat in the coastal low land along Purna river. The study was carried out in paddy and sugarcane growing areas of Navsari district which was represented by two villages namely Butlaw and Dabhalia (Fig. 1). Geologically this is a very young region. Accumulation of volcanic rocks principally formed by basaltic lava known as Deccan Trap is the single most

important and extensive geological formation. The climate of the area is sub-humid with the mean annual rainfall (1987-2016) of about 1623 mm, monthly rainfall pattern of the study area is represented in (Fig. 2). Water samples were collected randomly at a distance of 1-2 km by thorough covering the whole study area. Depths of the water table in the study area were ranged from 10 to 20 m during pre or post-monsoon seasons. The depth of water table was shallow in the areas along canals and towards Purna river, whereas in the areas where water table is closer to the land surface, waterlogging and salinization exist.

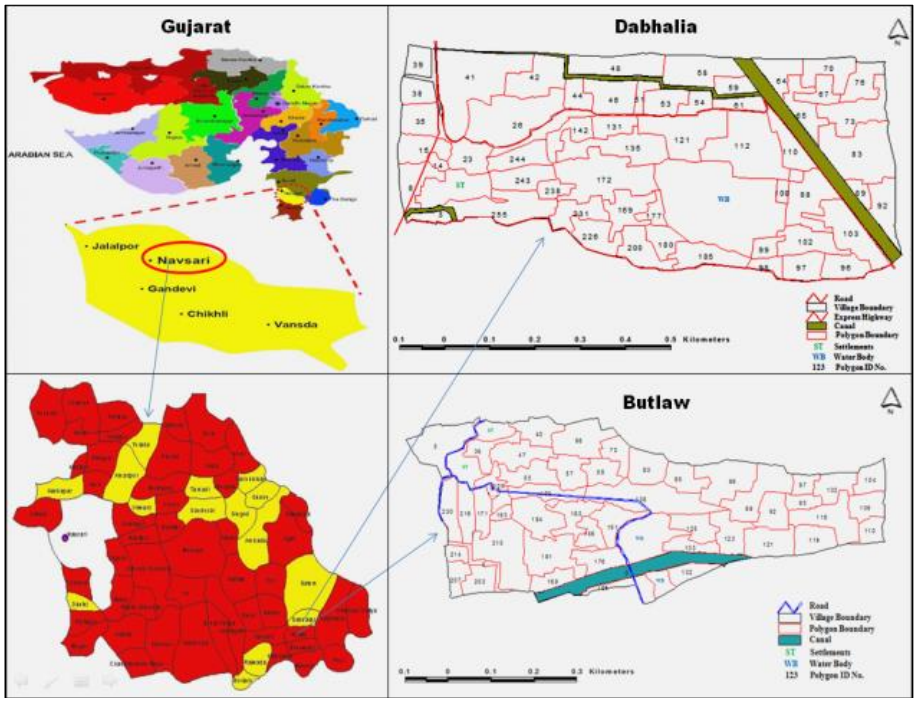

Fig 1: Location of the study area

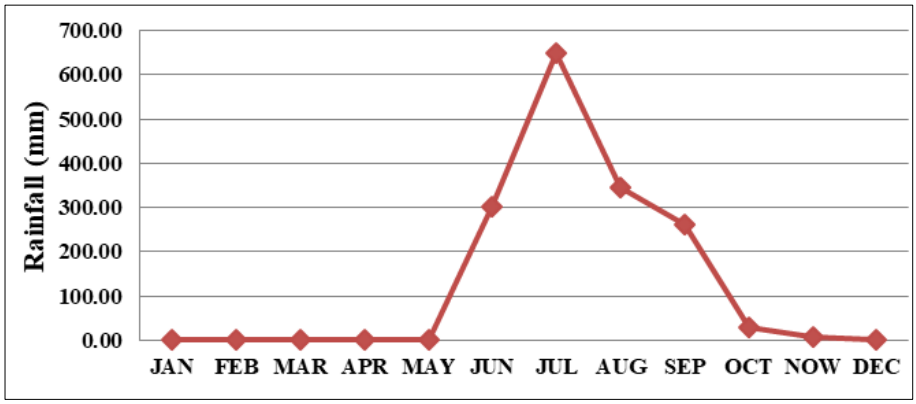

Fig 2: Monthly rainfall pattern (1987-2016)

Water sampling and analysis

Groundwater samples were collected from the bore wells and tube wells which were being used for irrigation purpose. From the whole study area in all 30 water samples were collected during pre-monsoon and post-monsoon seasons of 2016 by following standard procedure and preserved for chemical analysis. Running tube-wells distantly apart within each village were selected randomly for collection of water samples. Each selected tube-well was run for three to four hours and then the samples were collected in thoroughly cleaned plastic bottles, properly labelled and brought to the laboratory for further chemical analysis. Water samples were analyzed for pH, EC, cations (Ca^{2+}, Mg^{2+}, Na^{+}, K^{+}) and anions (CO_3^{2-}, HCO_3^{-}) by the standard methods outlined in the USDA Handbook 60 by Richards (1954) [5]. Quality of water samples for irrigation was evaluated based on EC and SAR following the procedure given by Richards (1954) and samples were classified.

Results and Discussion

Quality of water

pH

The pH of the water samples during the pre-monsoon season was found ranged from 7.25 to 7.81 with a mean value of 7.50 (Table 1) while in the case of the post-monsoon season it was found ranged from 7.17 and 7.67 with a mean value of 7.39 (Table 2). The mean pH value was found to be reduced during the post-monsoon season and a similar result was reported by Ghodke *et al.* (2016) [2]. The reason behind the relatively lower pH reported during the post-monsoon season might be due to the recharge of groundwater by high rainfall having lower pH during monsoon season in the study area. The range values indicate that in the study area 100% groundwater samples during pre-monsoon as well as post-monsoon season were neutral to alkaline in reaction. Histograms showing the frequency distribution of samples having different pH values during pre and post-monsoon season (Fig. 3).

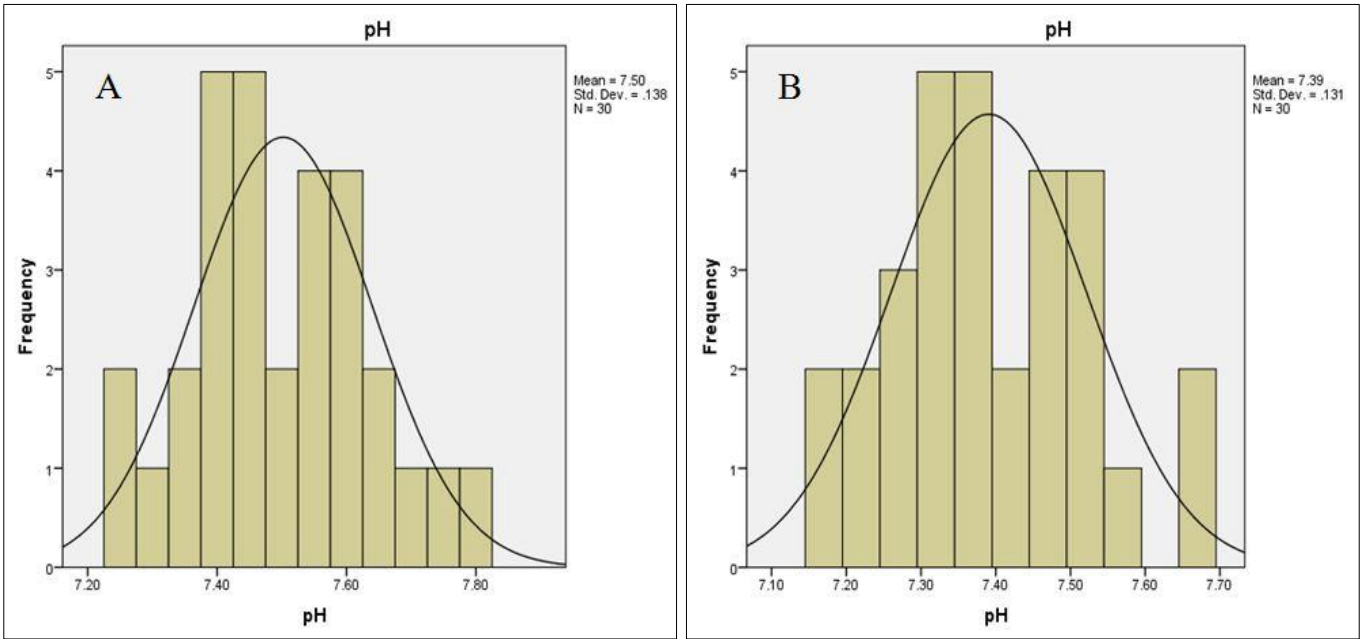

Fig 3: Histograms of pH characteristics of pre (A) and post-monsoon (B) water samples

Electrical Conductivity

From salinity point of view, EC of groundwater in the pre-monsoon season was ranging from 0.84 to 1.31 dS m^{-1} with a mean value of 1.01 dS m^{-1} (Table 1) while during the post-monsoon season it was found ranging from 0.77 to 1.22 dS m^{-1} with a mean value of 0.92 dS m^{-1} (Table 2). These range values suggest the presence of saline water in the study area and the 100% groundwater samples were classified in the C3 class for both the pre and post-monsoon season (Table 3). The reason behind groundwater salinity might be due to the location of the study area nearby coastal region and low groundwater table. Mean value shows that salinity reduced during the post-monsoon period, similar results were also reported by Ghodke *et al*. (2016) [2] and the reason behind might be dilution salts present in the groundwater due to high rainfall during monsoon season in the study area. Histograms showing the frequency distribution of samples having different EC values during pre and post-monsoon seasons (Fig. 4).

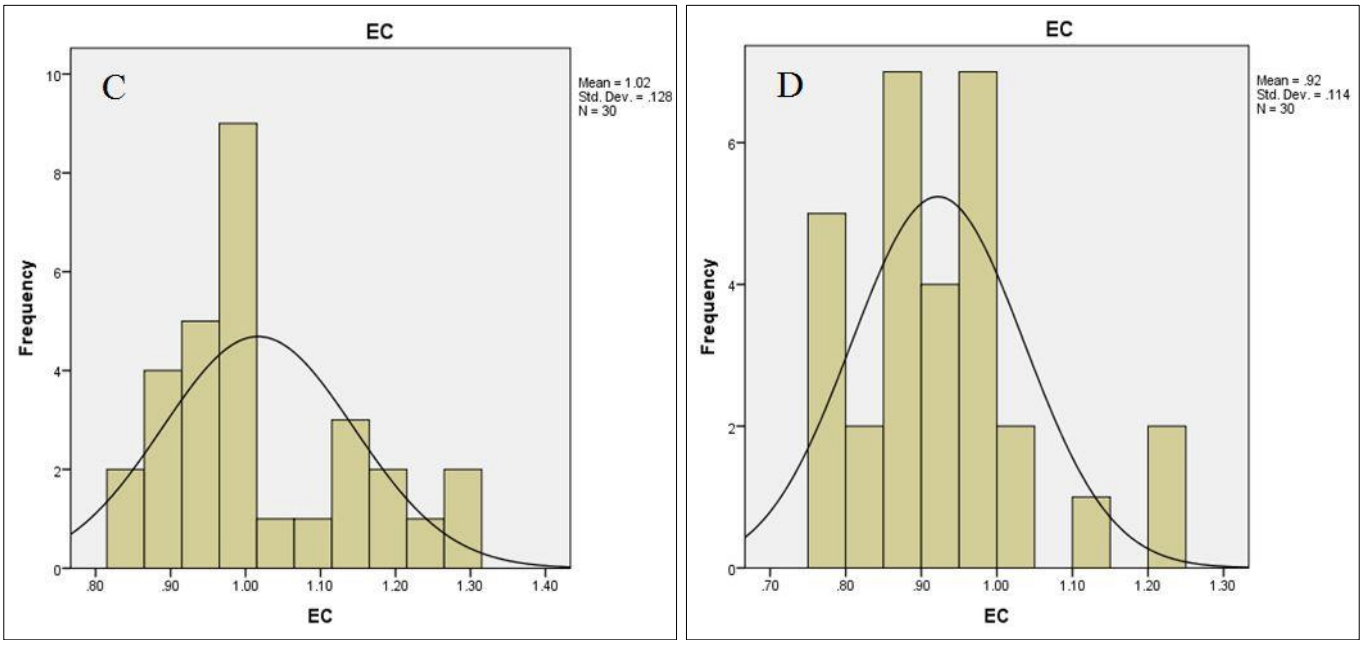

Fig 4: Histograms of EC characteristics of pre (A) and post-monsoon (B) water samples

Sodium Adsorption Ratio

Based on the content of soluble cations in the water samples, the index of sodicity hazard SAR was computed. The pre-monsoon season SAR was found ranged from 1.39 to 3.82 with a mean value of 2.77 (Table 1) while in the case of post-monsoon season SAR was found ranged from 1.27 to 3.74 with a mean value of 2.62 (Table 2). The higher mean value of SAR was found for pre-monsoon water samples than post-monsoon water samples and similar results were also reported by Ghodke *et al*. (2016) [2], the reason behind might be dilution salts present in the ground water due to high rainfall during monsoon season in the study area. Histograms showing the frequency distribution of samples having different SAR values during pre and post-monsoon seasons (Fig.5).

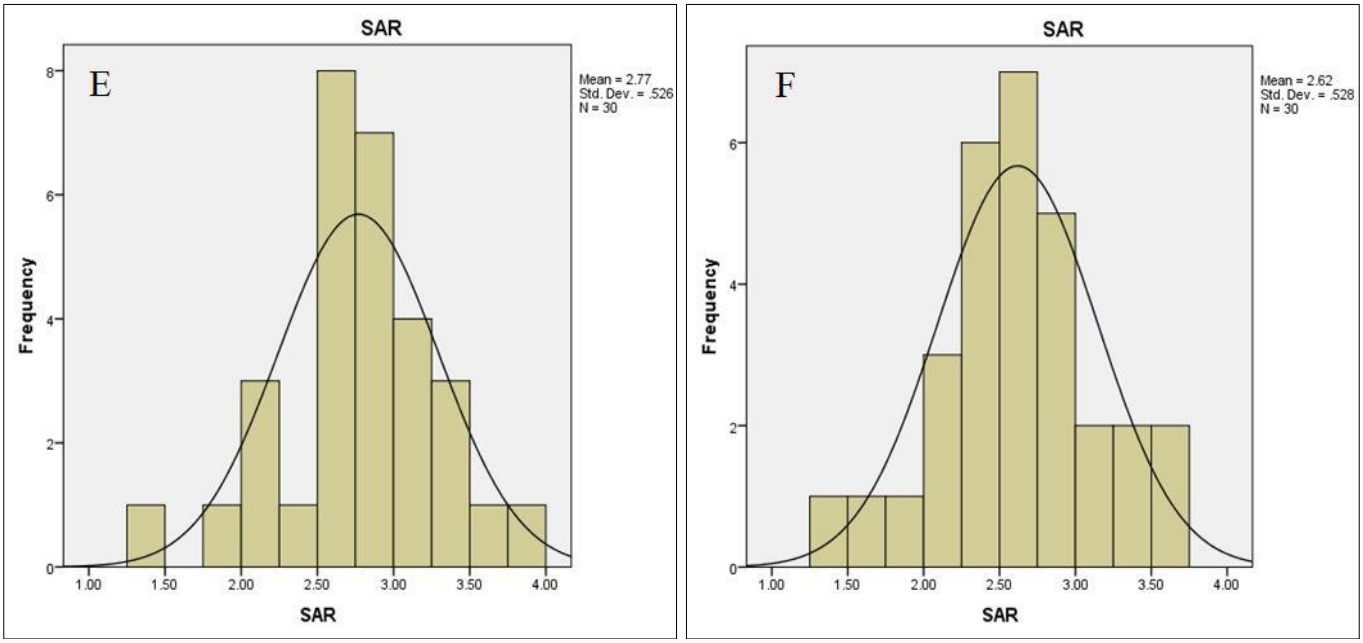

Fig 5: Histograms of SAR characteristics of pre (A) and post-monsoon (B) water samples

Residual Sodium Carbonate

Based on the content of soluble cations in the water samples, the index of sodicity hazard RSC was computed. The pre-monsoon RSC values of water samples were found ranged from 0.05 to 2.23 me L^{-1} with a mean of 0.98 me L^{-1} (Table 1) while for the of post-monsoon water samples it was found ranged from -0.10 to 2.23 me L^{-1} with a mean value of 0.92 me L^{-1} (Table 2). The higher mean value of RSC was found for pre-monsoon water samples than post-monsoon water samples, the reason behind might be dilution salts present in the ground water due to high rainfall during monsoon season in the study area, similar results were also reported by Ghodke *et al*. (2016) [2]. Histograms showing the frequency distribution of water samples having different RSC values during pre and post-monsoon seasons (Fig. 6).

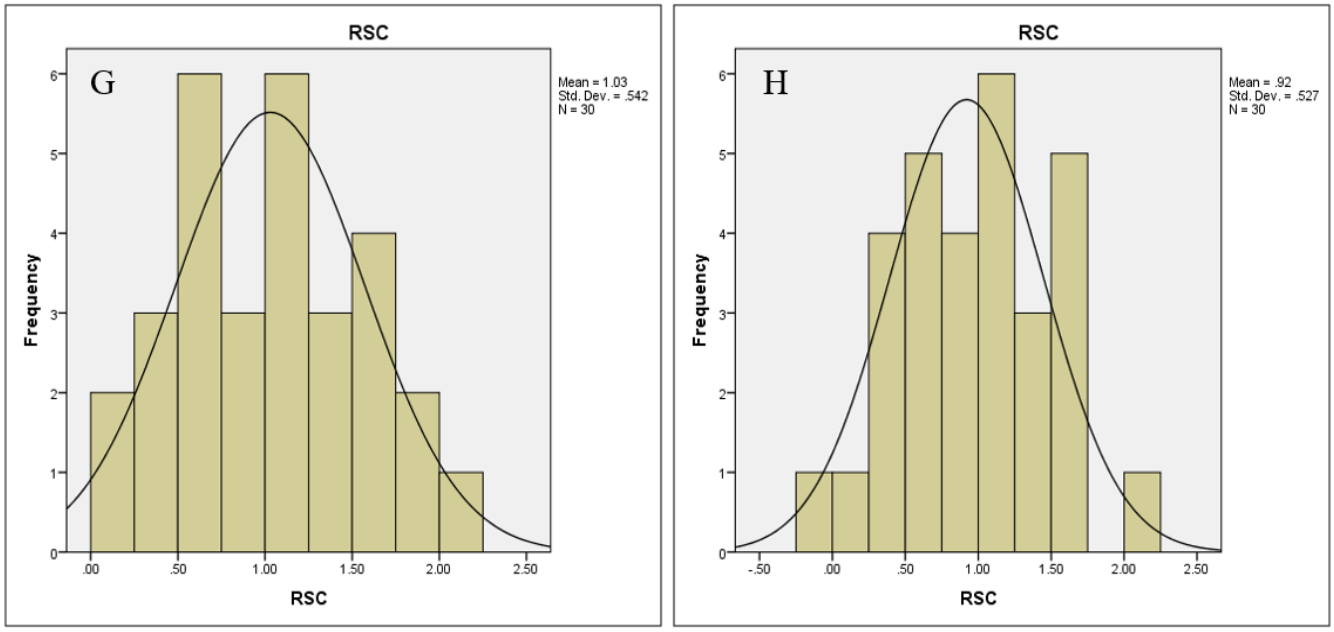

Fig 6: Histograms of pH characteristics of pre (A) and post-monsoon (B) water samples

Table 1: Descriptive statistics of different parameters of pre-monsoon groundwater samples

Pre-Monsoon Season							
Parameters	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**	**Skewness**	**Kurtosis**
pH	7.25	7.81	7.50	0.14	0.019	0.240	-0.212
EC	0.84	1.31	1.01	0.13	0.016	0.940	0.151
SAR	1.39	3.82	2.77	0.53	0.277	-0.420	0.913
RSC	0.05	2.23	1.02	0.54	0.294	0.133	-0.521

Table 2: Descriptive statistics of different parameters of post-monsoon groundwater samples

Post-Monsoon Season							
Parameters	**Minimum**	**Maximum**	**Mean**	**Std. Deviation**	**Variance**	**Skewness**	**Kurtosis**
pH	7.17	7.67	7.39	0.13	0.017	0.339	-0.460
EC	0.77	1.22	0.92	0.11	0.013	1.053	1.110
SAR	1.27	3.74	2.62	0.53	0.278	-0.249	0.840
RSC	-0.10	2.13	0.92	0.52	0.278	0.170	-0.446

Classification of water

Water samples were classified according to the classification given by L.A. Richards (1954) [5]. In terms of salinity hazard, all the water samples were classified as high-salinity water (C3) (Table 3). Such water cannot be used on soils with restricted drainage. Even with adequate drainage, special management for salinity control may be required, and plants with good salt tolerance should be selected. Whereas in terms of sodium hazards, all the water samples were classified as low-sodium water (S1) (Table 3) which means such water can be used for irrigation on almost all soils with little danger of the development of harmful levels of exchangeable sodium. But overall we can say due to the presence of salinity hazard in the groundwater, it will be better to use the surface water for irrigation purposes. If there is less availability of surface water, irrigation with groundwater should be done after ensuring well drainage facilities in the field. Otherwise, due to the clay texture of the soils in the study area accumulation of salt may occur in the field.

Table 3: Classification of water samples in to different classes of salinity and sodicity

Pre-monsoon				Post-monsoon			
Salinity hazard		**Sodium hazard**		**Salinity hazard**		**Sodium hazard**	
Class	**% sample**	**Class**	**% sample**	**Class**	**% sample**	**Class**	**% sample**
C1	-	S1	100	C1	-	S1	100
C2	-	S2	-	C2	-	S2	-
C3	100	S3	-	C3	100	S3	-
C4	-	S4	-	C4	-	S4	-

Simple Correlations

The pH of the water is found to be negatively correlated with the EC and RSC of the water during both the seasons but positively correlated with the SAR. EC was found to be positively correlated with the SAR and RSC during pre-monsoon season whereas it was found positively correlated with SAR and negatively correlated with RSC during post-monsoon season. SAR is found highly significantly correlated with the RSC during both the seasons (r=0.600** and r=0.592**), similar result was also reported by Ghodke *et al.* (2016) [2].

Table 4: Correlation of irrigation water quality parameters in pre and post-monsoon season

Pre-Monsoon Season					Post-Monsoon Season				
	pH	EC	SAR	RSC		pH	EC	SAR	RSC
pH	1.00	-0.052	0.046	-0.143	pH	1.00	-0.019	0.051	-0.110
EC		1.00	0.214	0.049	EC		1.00	0.106	-0.061
SAR			1.00	0.600**	SAR			1.00	0.592**
RSC				1.00	RSC				1.00

**Correlation is significant at the 0.01 level (2-tailed)

Conclusions

The pH of water samples in the study area was neutral to alkaline in nature. All the water samples were classified as high-salinity water (C3) groups and low-sodium water (S1) groups. During the post-monsoon season pH, EC, SAR and RSC values of the groundwater were found to decreased due to the dilution of groundwater during monsoon season. A highly significant positive correlation of SAR was found with the RSC during both the seasons (r=0.600** and r=0.592**). Due to the presence of salinity hazards in the groundwater, it will be better to use the surface water for irrigation purposes. If there is less availability of surface water, irrigation with groundwater should be done after ensuring well drainage facilities in the field. In addition to this, good soil water management strategies will help in maintaining adequate salt-water balance for appropriate crop growth.

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