Indian Journal of Ecology (2023) 50(5): 1265-1270
DOI: https://doi.org/10.55362/IJE/2023/4045

Manuscript Number: 4045
NAAS Rating: 5.79

Evaluation of Spatial Variability and Irrigation Water Quality of Groundwater in Prakasam District of Andhra Pradesh

P. Venkata Subbaiah, Y. Radhakrishna and M.J. Kaledhonkar[1]

AICRP on Management of Salt Affected Soils and use of Saline Water in Agriculture ANGRAU, Bapatla-522 101, India
[1]ICAR-Central Soil Salinity Research Institute, Karnal-132 001, India
** E-mail: venkat.076@gmail.com*

Abstract: A study was conducted in the year 2021 to evaluate spatial variability and irrigation water quality of groundwater in Praksam district, Andhra Pradesh. Representative 261 samples with GPS locations were collected. The groundwater samples were analyzed for pH, EC, Ca^{+2}, Mg^{+2}, Na^{+} and K^{+}; CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2}. The pH, electrical conductivity, SAR and RSC of groundwater ranged from 6.6-9.1, 0.5-31 (dSm^{-1}), 0.42-40.6 $(mmol\ l^{-1})^{1/2}$, -146 -19.4 (me l^{-1}). The concentration of cations *viz.,* Ca^{+2}, Mg^{+2}, Na^{+} and K^{+} varied from 0.8-48.0, 0.4-105, 0.7-355 and 0.004-30.04meq l^{-1}. Anions viz., CO_3^{-2}, HCO_3^{-}, Cl^{-} and SO_4^{-2} varied from 0.0-1.4, 1.6-21.8, 0.8-318 and 0.21-17.08 meq L^{-1}. Abundance of ions in ground water samples were Na^{+}> Mg^{+2}>Ca^{+2}> K^{+} for cations and HCO_3^{-}>Cl^{-}> SO_4^{-2}> CO_3^{-} for anions. According to CSSRI classification of irrigation water, 37.16, 27.20, 2.29, 8.81, 9.19, 6.89 and 8.42 per cent samples were good, marginally saline, Saline, High SAR Saline, marginally alkaline, alkali and highly alkali, respectively. Spatial variability maps of pH, EC, SAR, RSC and quality of groundwater for Prakasam were developed for monitoring of irrigation groundwater quality of the district.

Keywords: Prakasam ground water quality, EC, RSC, SAR, IWQI, Spatial variability

Agriculture is largely dependent on resources like soil and water. Water is very crucial for profitable crop production. Irrigation water quality affects the soil production by limiting the nutrient use efficiency of crop through salt buildup in the rhizosphere zone. In semi-arid and coastal regions due to limited or non-availability of good quality surface water increases the demand on poor quality groundwater as alternate source for irrigation (Gupta et al 2019). Groundwater plays a crucial role in agriculture for doubling of farmers income through intensification of crops on a unit land round the year. Good quality groundwater increases the crop production, sustains soil health and improves the nutrient use efficiency of crop. Farmers can accommodate more number crops and cropping systems along with suitable farming systems for sustaining farm income throughout the calendar year. In this context it is necessary to assess quality of groundwater in arid and semi -arid regions for irrigation. Keeping this in view a study was conducted to evaluate spatial variability and irrigation water quality of groundwater in Prakasam district of Andhra Pradesh.

MATERIAL AND METHODS

Study area: Prakasam district is located in Eastern coastal plain of hot sub humid to semiarid eco -region and lies in between 14°57' 00" and 16° 17' 00" of Northern latitudes and 78°43'00" and 80°25' 00"Eastern longitudes occupies central part of Andhra Pradesh. Prakasam has a total geographical area of 17,626 km^2. The district is bordered by Guntur district in North, east by Bay of Bengal with a coastal line of 102 km and on the South by Nellore and Kadapa districts, west by Kurnool district. Prakasam district has of 41163 tube wells and filter points and 22783 dug wells covering nearly 60 percent irrigated area of the district. Groundwater recharge for district is 142485 ha m. Total utilizable groundwater is 41499 ha m and present irrigation use is 8610 ha m. Groundwater development for district, considering all uses, is 29 percent. The major minerals of soil in weathered and fractured zone are granite, magnetite, quartz, silica sand, barytes, feldspars, slate stone, lime shell, laterite. Alluvial and colluvial materials are dominant in river plains and valley low lands. Shallow Red soils occupy 51%, deep black cotton soils in 41%, Sandy loam soils 6% and sandy soils 2% of the total area. Coastal line has fresh water in the areas around Chirala, Vetapalem, Chinnaganjam, Nagaluppalapadu, Kothapatnam, Ulavapadu and Tanguturu with thickness of 15.0 m due to presence sandy soils.

Analysis of groundwater: A total of 261 groundwater samples from different sources like bore wells and open wells collected. Around 5 to 6 samples were randomly collected from each mandal of Prakasam district with GPS coordinates (Fig. 1). Preconditioned clean high density polythene bottles were used for sampling, rinsed three times using sample prior to sample collection. The dug wells waters were lifted to the ground surface by rope and bucket while tube well waters were pumped to the surface by using hand pump. The pumps were run for 5-6 minutes prior to collection of water samples. Samples were collected in polyethylene bottles and immediately toluene was added to avoid microbiological deterioration. Standard procedures were (Table 1) followed to analyze the quality of water. Sodium Adsorption Ratio (SAR), RSC were calculated by using the formulas given by Richards (1954) such as SAR = Na/ $((Ca^{2+}+Mg^{2+})/2)^{0.5}$ and RSC = $(CO_3^{2-} + HCO_3^-) - (Ca^{2+} + Mg^{2+})$. The Na^+, Ca^{2+} and Mg2$^+$ are in m e L^{-1}. RSC, CO_3^{2-}, HCO_3^-, Ca^{2+} and Mg^{2+} are in meq L^{-1}. The RSC, SAR, KR, SSP, PI was computed for irrigation water quality index (IWQI).

Kelley's ratio: Kelley's ratio was used to classify the irrigation water quality (Kelley 1940), which is the level of Na^+ measured against calcium and magnesium. The formula for calculating the Kelley's is as follows

$$KR = \frac{Na^+}{(Ca^{+2} + Mg^{+2})}$$

Where the concentration of ions is in mg/L

Soluble sodium percentage (SSP): Sodium concentration in groundwater is a very important parameter in determining the irrigation quality. The formula used for calculating the sodium percentage (Wilcox 1955)

$$Na\% = (Na^+ + K^+)/(Ca^{+2} + Mg^{+2} + K^+ + Na^+) \times 100$$

Where all ionic concentrations are in meq/L.

Permeability index: Long-term use of irrigation contains Na^+, Ca^{+2}, Mg^{+2} and HCO_3^- ions greatly influence the soil permeability. Doneen (1964) expressed the degree of soil permeability in terms of permeability index (PI).

$$PI = \frac{(Na^+ + \sqrt{HCO_3^-})}{(Ca^{+2} + Mg^{+2} + Na^+)} \times 100$$

Where all ionic concentrations are in meq/L.

Statistical analysis and mapping: Research data were analyzed in SPSS 20.0 using Pearson correlation coefficient matrix to know significant variations between the physicochemical properties. Descriptive statistics were calculated using Microsoft Excel (Microsoft, WA, USA) spread sheet. Spatial distribution of groundwater quality was depicted in figures using Q-GIS 3.16.10.

RESULTS AND DISCUSSION

Spatial variability in pH of groundwater: The pH of water varied from 6.6 to 9.1(Table 2) with a mean of 7.6. The low pH may be due to presence of forest areas in certain pockets. Performance crops will be good at pH of groundwater is >6.5. Higher pH (>8.5) of ground water may be due to dominance of Na^+, Ca^{+2}, Mg^{+2} and CO_3^- and HCO_3^- ions and increases the clogging problems in emitters in pressurized irrigation system (Gupta et al 2019). The spatial variability of pH in groundwater in Prakasam (Fig. 2) indicate the suitability of groundwater for irrigation in majority of the district. Significant positive correlation observed between pH and CO_3^{-2} and RSC of groundwater. Vinothkanna et al (2020) with groundwater of Dindigul district and Naidu et al (2020) with Nellore district of Andhra Pradesh also expressed the same correlation with pH.

Spatial variability in electrical conductivity (EC) of groundwater: The EC values in water of various mandals of Prakasam district ranged from 0.5 to 31.0 dS m^{-1} with a mean

Table 1. Methods used for estimation of different hadrochemical parameters of groundwater

Parameters	Method used
pH	Glass electrode (Richards1954)
EC(Electrical conductivity)	Conductivity Bridge method (Richards1954)
Na^+ (Sodium)	Flame Photometric method (Osborn and Johns 1951)
K^+ (Potassium)	Flame Photometric method (Osborn and Johns 1951)
Ca^{+2}(Calcium)	EDTA titration method (Richards 1954)
Mg^{+2}(Magnesium)	EDTA titration method (Richards 1954)
CO_3^{-2}(Carbonate)	Acid titration method (Richards1954)
HCO_3^- (Bicarbonate)	Acid titration method (Richards1954)
Cl^- (Chloride)	Mohr's titration method (Richards1954)
SO_4^{-2} (Sulphate)	Turbidity method using $CaCl_2$ (Chesnin and Yien 1950)

Table 2. Range and average of quality parameters in groundwater of Prakasam district

Parameter	Range	Mean
pH	6.6-9.1	7.6
EC (dSm^{-1})	0.5-31.0	2.26
CO_3^{2-} (me L^{-1})	0.0-1.4	0.07
HCO_3^- (me L^{-1})	1.6-21.8	8.7
Cl^- (me L^{-1})	0.8-318	11.92
SO_4^{2-} (me L^{-1})	0.21-17.08	2.01
Ca^{2+} (me L^{-1})	0.8-48.0	4.93
Mg^{2+} (me L^{-1})	0.4-105	5.83
Na^+ (me L^{-1})	0.7-355	15.0
K^+ (me L^{-1})	0.004-30.04	0.69
RSC (me L^{-1})	-146-19.4	-1.98
SAR	0.42-40.6	7.40
KR	0.16-25.0	2.35
SSP	12.8-94.5	53.0
PI	27.3-119	68.8
IWQI	34-280	128

of 2.26 dS m^{-1} (Table 2, Fig. 3). Electrical conductivity is customarily used for indicating the total concentration of the ionized constituents of natural water.

The electrical conductivity classes (Table 3) were grouped into different classes up to 31 dSm^{-1}. Out of 261 samples collected 57.09 per cent samples had <2 dSm^{-1} followed by 30.65 per cent in range of 2-4 dSm^{-1} followed by 5.36 per cent in 4-6 dSm^{-1}, 2.30 per cent in 6-8 dSm^{-1} range, 2.68 per cent in 8-10 dSm^{-1} and 1.92 per cent in 10-31 dSm^{-1} range. The variation in EC may be due to variation in hydro-geological conditions and the anthropogenic activities of the region. Relationship between EC (dSm^{-1}) and total cations, total anions indicating that ionic constituents of groundwater samples exhibit positive correlation (Fig. 3a) with salinity of groundwater.

Concentration of cations: The cations viz., calcium, magnesium, sodium and potassium concentration in water samples varied from 0.8-48.0, 0.4-105, 0.7-355 and 0.004-30.04meq l^{-1} with mean values of 4.93, 5.83, 15.0 and 0.69 meq L^{-1} respectively. Concentration of cations followed the order sodium> magnesium >calcium >potassium. Dominance of Magnesium ion in groundwater indicates the mixing of seawater (Shalini and Bhardwaj 2017)

Concentration of anions: The anions viz., carbonate, bicarbonates, chloride and sulphate concentration varied from 0.0-1.4, 1.6-21.8, 0.8-318 and 0.21-17.08 meq L^{-1} with an average of 0.07, 8.70, 11.92 and 2.01 meq L^{-1}, respectively. The abundance of ions for most of the water samples are HCO_3^->Cl^-> SO_4^{-2}> CO_3^{-2}. The bicarbonate and chloride ions are dominant among all the anions then followed by sulphates and carbonates.

Spatial variability in sodium adsorption ratio (SAR): The SAR of Prakasam district groundwater ranged from 0.42-40.6 (m mol l^{-1})$^{1/2}$ with a mean of 6.27 (m mol l^{-1})$^{1/2}$. The lowest SAR of 0.42 (m mol l^{-1})$^{1/2}$ in water samples was observed in Voletivaripalem mandal and the maximum value of SAR was found as 40.6 (m mol l^{-1})$^{1/2}$ in Ongole mandal. Crop productivity will be adversely affected by continuous use of high SAR water due to decrease in soil infiltration rate (Gupta 2015). The spatial variability of SAR of groundwater in Prakasam district**,** indicated that the 4.22 % samples under high to very high hazard of Na^+ and are unsuitable for irrigation (Fig. 4 and Table 4).

Spatial variability in Residual Sodium Carbonate (RSC): The residual sodium carbonate (RSC) of groundwater in Prakasam district varied from -146-19.4 meq L^{-1} with a mean of -1.98meq L^{-1}. The highest RSC of 19.4 meq L^{-1} in water samples was in parts of Voletivaripalem mandal. The spatial distribution of RSC in groundwater was depicted in Figure 5 and observed that 75.48 % samples **(**Table 5) were of safe category, 9.96 % moderately suitable for irrigation and 14.56 % unsuitable for irrigation purposes, prolonged use of high RSC water may cause development of sodic soils due to a tendency of calcium to precipitate as carbonates (Subbaiah et al 2020).

Ionic correlation studies: The order of dominance is Na^+> Mg^{+2}>Ca^{+2}> K^+ for cations and HCO_3^->Cl^->SO_4^{-2}> CO_3^- for anions. Therefore, the chemical nature of the groundwater was characterized by Na^+- Mg^{+2}-HCO_3^--Cl^-water type. Highly significant correlation was observed between major cations and anions, Na^+ - Ca^{+2} (and Na^+- Mg^{+2}, Na^+ - Cl^- (r = and Na^+ - HCO_3^- and significant positive correlation between $Mg^{+2}$and Ca^{+2} (Mg^{+2} and Cl^-), and between Ca^{+2} and Cl^-(Table 6).

The Kelly's ratio was highly significantly positively correlated with pH, EC and Na^+ at 1% level of significance. The RSC of groundwater had high positive correlation with pH, CO_3^{-2}, HCO_3^- and negative with Ca^{+2} and Mg^{+2}. Indicates that continuous use of irrigation water with high RSC (>2.5 meq L^{-1}) increases the exchangeable sodium percentage and pH of soil and adversely affects the infiltration rate of the soil (Gupta et al 2019). The PI has significantly positive with pH and bicarbonates.

Classification of ground water quality for irrigation purpose: The groundwater of Prakasam district was classified into seven classes for irrigation purpose (Minhas and Gupta 1992). The 37.16 % were of good quality, 27.20 % were of marginally saline, 2.29 % of saline, 8.81% high SAR saline, 9.19 % of marginally alkali, 6.89 % of alkali and 8.42% of highly alkali (Table 7). Spatial variability in irrigation water quality of groundwater (Fig. 6). The quality of groundwater influenced by various factors like topography, lithology, geological structure, depth of weathering, extent of fractures, drainage pattern, climate conditions (CGWB, 2019). Kelley's ratio for all the groundwater samples is calculated and it lies between 0.15 to 33.04 mg/L. Kelley's ratio value (Table 8) less than one is suitable for irrigation (28.35 %) and more than one is unsuitable (71.65 % samples). Soluble sodium percentage (SSP) value <50 indicates (Table 9) good for irrigation (40.23 %) and >50 indicates not good for irrigation (59.77 %). Permeability index (PI) value indicates 37.55 per cent samples suitable for irrigation and 62.45 per cent samples marginally suitable for irrigation (Table 10). The higher concentration of bicarbonate ions in groundwater reacts with Ca and precipitate as $CaCO_3$ and reduces the permeability of soil (Gupta et al 2019).

Irrigation water quality index (IWQI) was computed by using water quality indices viz., SAR, RSC, KR, SSP and PI. The indices values were summed and then classified into excellent to unfit groundwater quality (Table 11). The 64.75% of groundwater was found poor in quality and slightly

Table 3. Ground water quality based on electrical conductivity (dSm^{-1})

EC (dSm^{-1})	No. of samples	Per cent of samples
0-2	149	57.09
2-4	80	30.65
4-6	14	5.36
6-8	6	2.30
8-10	7	2.68
10-31	5	1.92

Table 4. Classification of ground water based on SAR

SAR	No. of samples	Per cent of samples
<10	214	81.99
10-18	36	13.79
18-26	6	2.30
>26	5	1.92

Table 5. Classification of ground water based on RSC (mel^{-1})

Residual sodium carbonate (mel^{-1})		No. of samples	Per cent of samples
Class	Value		
None	<2.5	197	75.48
Slight to moderate	2.5-4.0	26	9.96
Severe	>4.0	38	14.56

Table 8. Classification of groundwater for irrigation based on Kelly's ratio (Kelly 1940)

Kelly's ratio	Suitability	Sample	
		Numbers	Per cent
<1.0	Good	74	28.35
>1.0	Not good	187	71.65

Table 6. Correlation matrix among the chemical constituents of the groundwater

	pH	EC	Ca^{+2}	Mg^{+2}	Na^{+}	K^{+}	Cl^{-}	HCO_3^{-}	CO_3^{-2}	SO_4^{-2}	RSC	SAR	KR	SSP	PI
pH	1														
EC	-0.111	1.000													
Ca^{+2}	-0.375	0.771**	1.000												
Mg^{+2}	-0.161	0.902**	0.817**	1.000											
Na^{+}	-0.027	0.944**	0.688**	0.885**	1.000										
K^{+}	-0.112	0.286**	0.275**	0.220**	0.101	1.000									
Cl^{-}	-0.125	0.931**	0.814**	0.948**	0.946**	0.178	1.000								
HCO_3^{-}	0.105	0.287**	-0.052	0.121	0.236**	0.238	0.121	1.000							
CO_3^{-2}	0.367**	-0.004	-0.133	-0.046	0.026	-0.057	-0.051	0.142	1.000						
SO_4^{-2}	-0.012	0.102	-0.105	-0.086	-0.077	-0.094	-0.097	-0.042	0.004	1.000					
RSC	0.277**	-0.792	-0.916**	-0.920**	-0.764	-0.179	-0.885	0.221	0.136	0.083	1.000				
SAR	0.223	0.716	0.245	0.449	0.754**	0.049	0.586	0.531	0.169	-0.044	-0.233	1.000			
KR	0.418**	0.217**	-0.195	-0.031	0.289**	-0.047	0.109	0.519**	0.264**	0.017	0.240**	0.798**	1.000		
SSP	0.297**	0.303**	-0.154	0.034	0.356**	0.083	0.204	0.561**	0.113	0.011	0.193	0.750	0.744	1.000	
PI	0.406**	0.027	-0.410	-0.183	0.161	-0.097	-0.011	0.437**	0.146	0.069	0.395**	0.556**	0.689	0.898	1.000

Note: RSC= Residual Sodium Carbonate ; SAR= Sodium Adsorption Ratio; KR = Kelly's Ratio; SSP= Soluble sodium percentage; PI= Permeability index
* Significant at 0.05 Probability level, **Significant at 0.01 probability

Table 7. Classification of Groundwater for irrigation (Minhas and Gupta 1992)

Rating	EC (dSm^{-1})	SAR	RSC (me L^{-1})	Number of samples	Per cent samples
A. Good	<2	<10	<2.5	97	37.16
B. Saline					
Marginally saline	2-4	<10	<2.5	71	27.20
Saline	>4	<10	<2.5	6	2.29
High SAR saline	>4	>10	<2.5	23	8.81
C. Alkali water					
Marginally alkaline	<4	<10	2.5-4.0	24	9.19
Alkali	<4	<10	>4.0	18	6.89
Highly alkaline	variable	>10	>4.0	22	8.42

Table 9. Classification of groundwater based SSP for irrigation (Richards 1954)

Kelly's ratio	Suitability	Sample	
		Numbers	Per cent
<50	Good	105	40.23
>50	Not good	156	59.77

Table 10. Classification of groundwater based on permeability index (PI) for irrigation (Doneen1964)

Classification of PI	Permeability	Suitability	Sample	
			Number	Per cent
I	>75	Suitable	98	37.55
II	25-75	Marginal	163	62.45
III	<25	Unsuitable	0	0.0

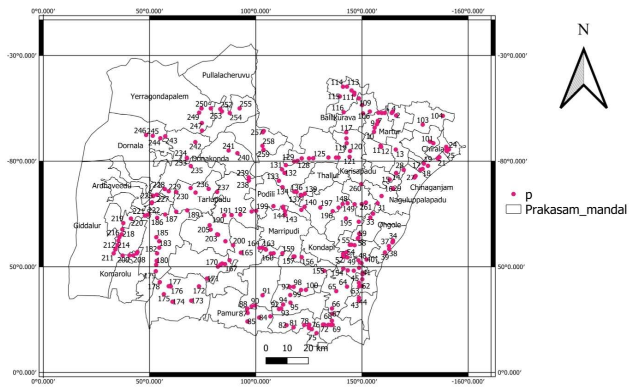

Fig. 1. Ground water sampling points in Prakasam district

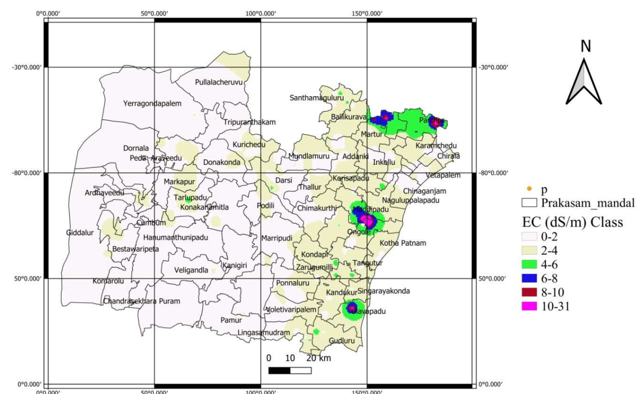

Fig. 3. Spatial distribution of EC (dS/m) in ground water of Prakasam district

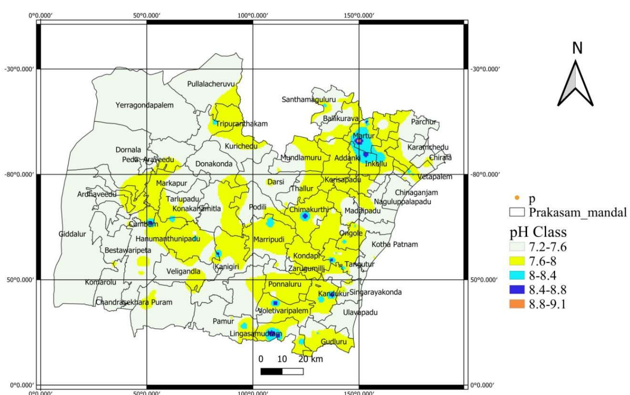

Fig. 2. Spatial distribution of pH in groundwater of Prakasam district

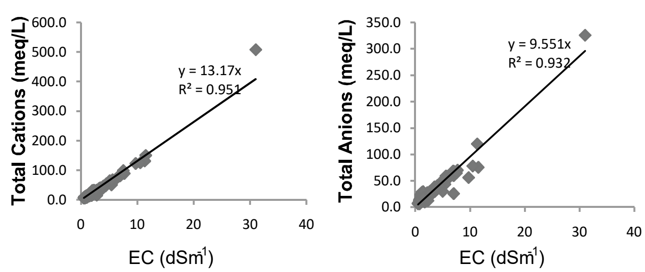

Fig. 3a. Relationship between EC and ionic constituents of groundwater

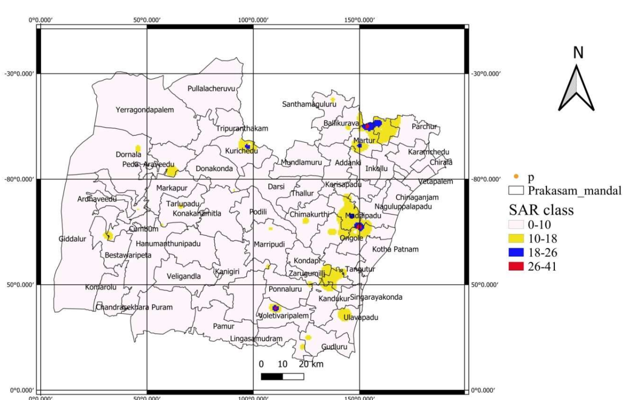

Fig. 4. Spatial distribution of SAR in groundwater of Prakasam district

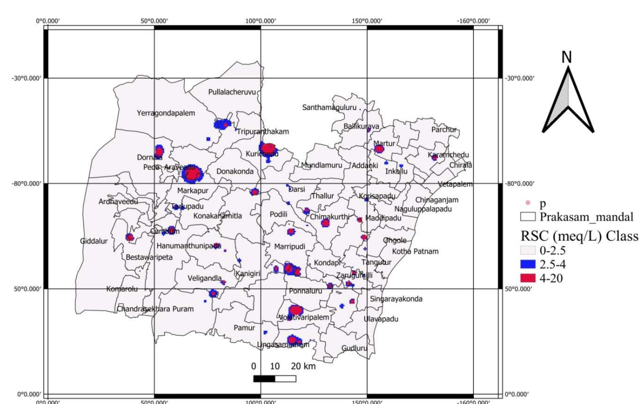

Fig. 5. Spatial distribution of RSC (meq/l) in groundwater of Prakasam district

Table 11. Classification of groundwater based on IWQI for irrigation

Water value range	Water quality	No. of samples	Per cent samples	Sustainable state
<50	Excellent	8	3.07	Sustainable
51-100	Good	66	25.29	Sustainable
101-200	Poor	169	64.75	Slightly unsustainable
201-300	Very poor	18	6.90	Unsustainable
>301	Very bad	8	3.07	Highly unsustainable

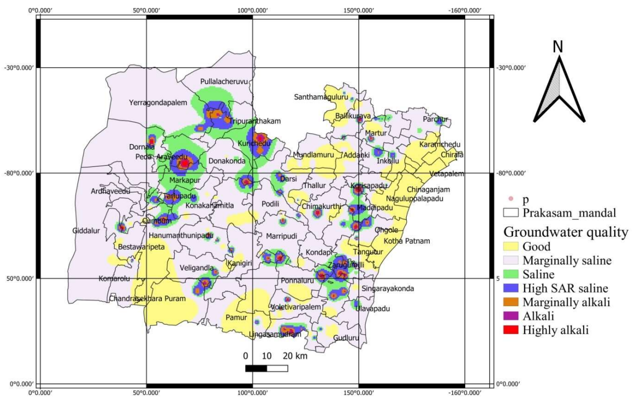

Fig. 6. Spatial distribution of groundwater quality in Prakasam district

unsustainable for irrigation, 6.9% was found very poor and unsustainable in quality, 3.07% was very bad and highly unsustainable, only about 3.07 % in excellent quality and 25.29% in good quality for irrigation. The results were in conformity with Kumar and Kumar (2021).

CONCLUSIONS

The groundwater quality in Prakasam district differed from place to place. The dominance of major ion was in the order of Na^{+}> Mg^{+2}>Ca^{+2}> K^{+} for cations and HCO_3^-> Cl^-> SO_4^{-2}> CO_3^- for anions, which indicated the quality of irrigated groundwater is Na^+- Mg^{+2}-HCO_3^--Cl^- type. The spatial maps of different parameters, prepared using GIS could be valuable for policy makers for initiating groundwater quality monitoring of the area as well as for suggesting management plans for the farmers in selection of suitable crops and other agronomic management practices for getting profitable yields without affecting the soil health. The results showed that 64.75% groundwater of Prakasam district were found poor in the quality and slightly unsustainable for prolonged use. About 6.9 % samples very poor and unsustainable, 3.07 % samples are very bad in quality highly unsustainable for irrigation. About 8% samples are excellent and 25.29 % samples are good and sustainable to use for irrigation.

Received 04 April, 2023; Accepted 02 September, 2023

ACKNOWLEDGEMENTS

Authors thank the Indian Council of Agricultural Research and ICAR- Central Soil Salinity Research Institute, Karnal for providing financial and technical support, respectively, for conducting this research under AICRP on Management of Salt Affected Soils and Use of Saline Water in Agriculture at Bapatla Centre in Andhra Pradesh.

REFERENCES

Chesnin L and Yien CH 1950. Turbidimetric determination of available sulphates. *Proceedings of Soil Science Society of America* **14**: 149-151.

Doneen LD 1964. *Notes on water quality in agriculture. Water Science and Engineering Paper 4001*, California, Department of Water Sciences and Engineering, University of California.

Gupta SK2015. Assessing the hazards of high SAR and alkali water: A critical review. *Journal of Soil Salinity and Water Quality* **7**: 1-11.

Gupta SK, Sharma PC and Chaudary SK 2019. *Hand book of Saline and alkali soils diagnosis, reclamation and Management.* Scientific Publishers (India), Jodhpur.

Jackson ML1973. *Soil Chemical analysis*. Prentice Hall of India Pvt. Ltd. New Delhi, pp.134-182.

Kelley WP 1940. Permissible composition and Concentration of Irrigation waters. In: *Proceedings of the ASCE* 66, pp 607.

Kumar V and Kumar V 2021. Evaluation of groundwater quality and suitability for irrigation in Nathusari Chopta block of Sirsa district (Haryana, India) using Geo-informatics. *Indian Journal of Ecology* **48**(1): 8-12.

Minhas PS and Gupta RK 1992. *Quality of irrigation water: Assessment and management*. ICAR, New Delhi. pp123.

Naidu MVS, Subbaiah PV, Radhakrishna Y and Kaledhonkar MJ 2020. Evaluation of ground water quality for irrigation in various mandals of Nellore district in Andhra Pradesh. *Journal of the Indian Society of Soil Science*, **68**(3): 288-297.

Osborn GH and Johns H 1951. The rapid determination of sodium and potassium in rocks and minerals by flame photometry, *Analyst* **76 :** 410-415.

Richards LA 1954. *Diagnosis and improvement of saline and alkali soils*. Agricultural Hand Book No.60, USDA, Washington DC, 160.

Shalini C and Bhardwaj SK 2017. Effect of different land use on quality of water in Solan Block of Himachal Pradesh. *Indian Journal of Ecology* **44**(4): 808-812.

Subbaiah PV, Naidu MVS, Radhakrihsna Y and Kaledhonkar MJ 2020. Groundwater quality assessment for Chittoor district of Andhra Pradesh for Irrigation purpose and Management options. *Journal of Soil Salinity and Water Quality* **12(1)**: 1-14.

Vinothkanna S, Rajee and Rajee R and Senthilraja K 2020. Assessing groundwater quality for the suitability of irrigation in Dindigul district, Tamil Nādu, India. *Indian Journal of Ecology* **47**(1): 23-29.