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Groundwater Quality Status of the Parambikulam Aliyar Palar Basin, Tamil Nadu, India Using RS and GIS Techniques

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The dependency of ground water is rising day by day. The ground water gets recharged mainly through rainfall. Thirty five water samples were collected from Parambikulam Aliyar Palar basin from open wells, bore wells and dug cum bore wells and analysed for chemical properties such as pH, Electrical Conductivity, cations and anions for two years duration (2020 and 2021) at three months interval (summer, winter, southwest monsoon, northeast monsoon) and analysed for the quality parameters. T Electrical conductivity values were ranged from 0.3 to 5.19 dsm^{-1}, 0.29 to 6.80 dsm^{-1} 0.3 to 6.84 dsm^{-1} and 0.64 to 4.17 dsm^{-1} during south west, north east, winter and summer seasons of 2020, respectively. The salt content was slightly increased during winter and summers seasons as compared to south west and north east. he samples were classified under USSL classification. Most of the samples come under medium salinity class (C_2) (48.57%) followed by low salinity class (C_1), high salinity class (C_4) and very high salinity class (C_3) with 28.57, 14.29 and 8.57 per cent respectively in all the seasons. Majority of the samples exhibit there is no permeability hazard. Salinity persists in the basin and possibility of salt accumulation in irrigation pipes observed from LSI values. Using remote sensing and GIS technique, the mapping was done for the groundwater quality of PAP basin. The variations in the ground water quality of the basin are directly positively correlated with rainfall pattern and geology of the basin. For effective utilization of saline water in the basin, management strategies were formulated and field experiments were conducted in the farmer's holdings in the sampling area of the basin.

Keywords: Groundwater; quality; PAP basin; RS and GIS.

1. INTRODUCTION

Groundwater is generally less susceptible to contamination and pollution when compared to surface water bodies. Pollution of groundwater due to industrial effluents and municipal waste in water bodies is major concern in many cities and industrial clusters in India. It leads to deterioration of groundwater quality [1]. Irrigation of poor quality water through the extraction of groundwater from deep aquifers leads to salinisation of the agricultural soils. An estimate on extent of poor quality water irrigation and sources of the poor quality water will give a real picture for adopting management strategies for remediation. The highest value of EC of >8.0 dSm-1 is observed in Chinnapoolanginar. Hence this study was taken to assess the groundwater quality of PAP basin in Tamil Nadu [2].

2. STUDY AREA

Parambikulam-Aliyar basin is located in the south western part of the Peninsular India, and covers the areas in Kerala and Tamil Nadu States. There are about 34 river basins in Tamil Nadu which are grouped into 17 major river basins Out of 17 river basins, many basins are water deficient and some have surplus water [3] Aliyar river rises in the eastern slopes of Anamalai hills of the Western Ghats is Coimbatore district is at an elevation of 2250 m above MSL and flows in the north-westerly direction on its 45 km runs from its origin, it is joined by a tributary namely the Palar river on its right bank traversing by another 15 km westwards, it enters the Palaghat district of Kerala State through Palaghat gap. Parambikulam river and Sholayar river are the tributaries of the Chalakudi river (flowing in Kerala State). It has its origin from the western slope of Anamalai hills of Western Ghats and flows in west – south westerly direction. Parambikulam-Aliyar river basin has an undulating topography with maximum contour elevation in the plain is 300 m and the maximum spot height in the plain is 385 m above MSL. One third of the basin area (822.73 km^2) is covered with hills and dense forest cover. The total area of PAP basin is 2388.72 km^2. This basin is bounded in north and east by Cauvery basin, south and west by Kerala State. This basin area lies (except the ayacut area) within the coordinates of between 10° 10' 00" N to 10°57'20" and 76°43'00" to 77° 12'30" E [4].

The PAP basin area lies (except the ayacut area) within the coordinates between 10° 10' 00" to 10°57'20" N and 76°43'00" to 77° 12'30" E. The basin area lies within the Coimbatore district only and the ayacut area is extent beyond Coimbatore district up to Tiruppur and Erode districts share the basin area. The total command area worked out to 1,74,553 ha. . The water samples were analysed for quality parameters as per the standard procedure given by Richards [5]. Classification of quality of irrigation water was done as per standard procedures. Residual Sodium Carbonate (RSC) was classified as per Eaton [3] and Wilcox, et. al. [6] and salinity and sodicity classes were classified as per Richards [5]. Residual Sodium Bicarbonate was calculated and classified based on Gupta and Gupta [7]. The results were also interpreted as per Ayers and Westcot [8] where the quality of irrigation water was interpreted based on the degree of salinity.

2.1 Sub Basins

Sub basins are Sholayar, Aliyar and Palar.

Sholaiyar sub basin: Sholaiyar sub basin has no direct Ayacut.

2.1.1.Aliyar sub basin

Aliyar sub basin has an old ayacut to an extent of 2,591 ha and new ayacut to an extent of 1,796 ha. Five canals from old ayacut and four canals from new ayacut irrigate about 20,558 ha.

2.1.2 Palar sub basin

Palar sub basin has old Ayacut to an extent of 1,302 ha. It has two components one being system tanks and other being direct Ayacut. New Ayacut is 15,263 ha. In total the irrigation area under Palar sub basin is 1,74,553 ha.

2.2 Irrigation System in the PAP Basin

The Aliyar sub Basin area of 20536 ha including old command is irrigated through four canals. The entire command area has been divided into two zones viz. A & B and each zone gets irrigation for a period of 135 days (4 ½ months) once in two years.

Irrigation pattern:

2.2.1 Aliyar sub basin

Old Ayacut includes double crop/ wet and irrigation season being 15th May to 31st March. New Ayacut includes double crop per dry and irrigation season being 1st September to 15th January in two zones A and B.

2.2.2 Palar sub basin

Old Ayacut includes double crop wet. Irrigation season I begins on 1st August and up to 31st December. Irrigation season II begins on 1st and upto 31st May. New Ayacut includes irrigated dry (I.D) crops. Irrigation schedule in the range once in two years. *i.e.,* each zone will get supply in alternate years.

2.3 PAP Command Area

Parambikulam Aliyar Project command comes under Aliyar and Palar sub-basins. Pollachi main canal (New ayacut) of Aliyar sub-basin which extends up to a length of 48 kms with 30 distributaries. The 4(L) distributary of Pollachi main canal located at 5.22 kms has been selected for in depth water management study where the entire command has been divided into A zone and B zone. Each zone gets canal supply once in alternate years. The area under A zone and B zone are 226.96 ha and 265.01 ha respectively. Apart from canal supply, there are 103 bore wells and 95 open wells in the command area.

2.4 Details of Crop Grown in PAP Basin

The crops such as Coconut, Silk Cotton, Mango, Tomato, Chillies, Bhendi, Sorghum, Grass Moringa, Banana, Arecanut, Cowpea, Teak, Jack, Horse gram, Sugarcane, Maize, Amla, Sapota and Guava were grown in the basin and irrigation practices followed are Micro Irrigation and Flood Irrigation

2.5 Soil Type in the PAP Basin

In this sub basin, due to different stages of weathering and parent materials, the soil types are met with combination of Inceptisol, Alfisol and Entisol. More prominent type is Inceptisol. Inceptisol : Red or brown or grey soil with surface horizon more developed than sub surface. They are developing soils, moderately deep, coarse loamy to loam moderately drained to well drained and suited for commonly grown crops with exceptions. Alfisol & Entisol : The red or brown soils having accumulation of illuviated clay in sub surface horizon it well drained, poor water and nutrient holding capacity and annual crops with shallow roots systems comes up well. In Aliyar sub-basin mostly the soil is red loam, sandy loam , reddish gravel , black clayey soils and black soils with pH - ranging from 7 to 8.9.

2.6 Geology of the Study Area

Geologically, the area is comprised of crystalline rocks of Archaean age. Charnockites form the major rock type of the basin followed by granites, granitic gneisses, dunites, limestones, quartzite basic and ultra basic intrusives of pegmatites and quaternary veins. Charnockites and associated migmatites occupy a major part of the area. The Anamalai hill ranges are composed of charnockites and their magmatised equivalents. Granites intruded into the older gneisses and charnockites and have undergone metamorphism and metasomatism. They occupy mostly small mounds or linear domes in the area. Hornblende, biotite, gneisses occupy the central and northern portion of the basin area (Fig 3). The thickness of laterites seldom exceeds 15m. The thickness of weathered zone is 9.3 to 10 m. The lineaments traversing to a length of 10-15 kms in NW –SE direction are predominant. Several patterns of sheared and fractured zones are noticed along contact zones and also between varied geological formations. Geomorphologic maps help to identify the various geomorphic units and ground water occurrence and quality.

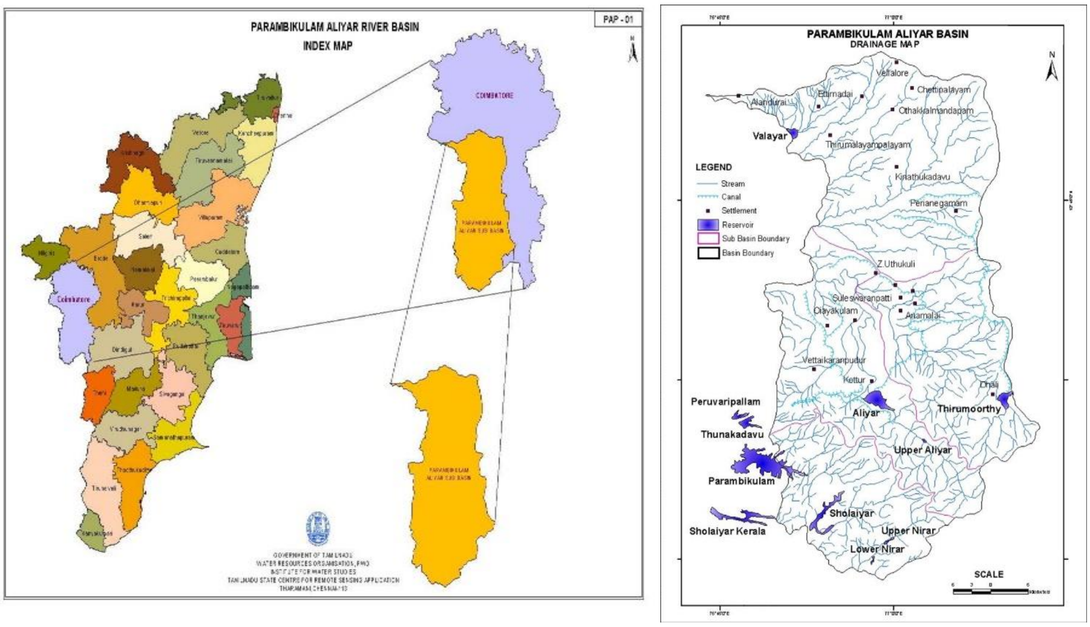
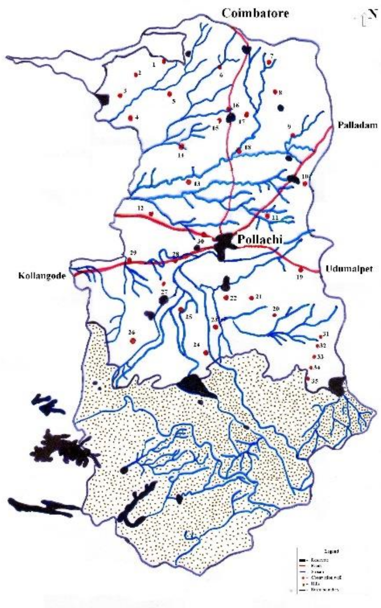


Fig. 1. Location and drainage map of the PAP basin (Source: PWD)



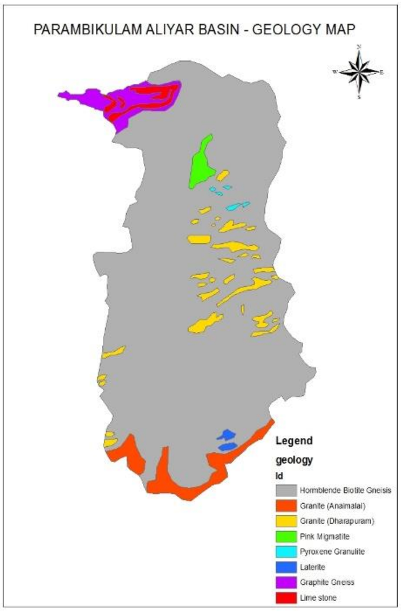


Fig. 2. Location of the sampling wells **Fig. 3. Geology map of PAP basin**

3. MATERIALS AND METHODS

3.1 Collection of Ground Water Samples

Thirty five water samples covering the entire PAP basin were collected from open wells, bore wells and dug cum bore wells during south west, north east, winter and summer seasons of 2020 and 2021 and analyzed for irrigation water quality parameters. Observation wells are spread over the entire basin area (Fig. 2). The irrigation wells in the study area are broadly grouped as dug wells, dug-cum-bore wells and shallow bore wells. The groundwater extraction is worked out based on the cropping pattern and the existing number of wells and their categories.

4. RESULTS

Thirty five water samples were collected from Parambikulam Aliyar basin from open wells, bore wells and dug cum bore wells during south west, north east, winter and summer seasons of 2020 and 2021 (Four seasons) and analyzed for chemical properties like EC, pH, cations and anions (Fig. 4). Permeability index or Doneen's Permeability Index was calculated as per Doneen, (1966) as follows. problems on soils and toxicity of ions. EC and Sodium Adsorption Ratio (SAR) Permeability Index Na + + (HCO−) 1/ 2 = 3 ×100 Ca2+ + Mg 2+ + Na +

4.1 Salinity (EC)

The total soluble salts in irrigation waters are estimated in terms of electrical conductivity (EC). The water with an EC of less than 750 dsm^{-1} is considered as an ideal value [5] and >2250 µS/cm is suitable for agricultural purposes except for some sensitive crops. Excess salt in the irrigation water will increase the salinity of the soil solution and hence the plants cannot maintain the osmotic balance. This will lead to the drooping of crops (Zamann et al., 2018).Electrical conductivity values were ranged from 0.3 to 5.19 dsm^{-1}, 0.29 to 6.80 dsm^{-1} 0.3 to 6.84 dsm^{-1} and 0.64 to 4.17 dsm^{-1} during south west, north east, winter and summer seasons of 2020, respectively. The salt content was slightly increased during winter and summers seasons as compared to south west and north east. This may be due to the decreased water table / level in the open and bore wells (Table 3). During 2021, the similar results were obtained. The samples were classified under USSL classification [5].

4.2 pH

Natural waters will be having the pH values from 6 to 8.5. The water with pH values >8.5 may contain appreciable amount of sodium carbonates and bicarbonates. pH or hydrogen ion concentration is the important parameter of water that determines the suitability of water for various purposes such as drinking, domestic, irrigation, and industrial uses. Highly utilized by people for domestic purposes such as washing, bathing etc. This increases the soap content in water. The pH of 7 is said to be neutral, below 7 is considered acidic and above 7 is considered as basic or alkaline. The safe pH range for any intended use is designated as 6.5 to 8.5 by BIS, 2012. The pH of all the collected samples ranged from 7.2 to 8.6 and is found to be slightly alkaline, which may be attributed to the release of textile effluents and sewage disposal. pH values ranges from 6.63 to 7.98 during SW, 6.6 to 8.4 during NE, 7.10 to 8.20 during winter and 7.0 to 8.6 during summer, 2021. In most of the samples, pH values were decreased during SW and NE when compared to winter and summer.

In generally accepted sense, Dissolved gases such as CO_2, H_2S, and NH_3 also affect the pH of water. The industrial waste water will be strongly acidic or basic and their effect on the pH value of receiving water depends on buffering capacity of water. Higher value of pH has a bitter taste.

4.3 Cations

The samples were analyzed for cations like calcium, magnesium, sodium and potassium. The cations content of the water samples increased during summer season. During 2021, the similar results were obtained. The cations were more during the summer and winter than southwest and north east monsoon seasons.

4.4 Calcium

Calcium content ranged from 0.60 to 2.90 m.e L^{-1}, 0.80 to 3.10 m.e L^{-1}, 0.90 to 3.20 m.e L^{-1} and 1.20 to 3.50 m.e L^{-1} during south west, north east, winter and summer seasons of 2020-2021, respectively. Calcium and magnesium enter the water mainly by leaching of rocks. Most calcium in surface waters come from streams flowing over limestone, dolomite, gypsum, and other calcium-containing rocks and minerals.

4.5 Magnesium

Magnesium hazard was calculated by Mg2+ to Ca2+ ratio [5] Magnesium content varied from

1.00 to19.1 m.e L^{-1}, 1.2 to 26.0 m.e L^{-1}, 0.0 to 26 m.e L^{-1} and 1.00 to 26.5 m.e L^{-1} during south west, north east, winter and summer seasons of 2020-2021, respectively. Most of the samples were found to be with magnesium dominating water. Magnesium exceeds the calcium content in most of the water samples both during south west, north east, winter and summer seasons of 2020-2021, respectively. Magnesium toxicity will be exhibited in continuous use of water to crops. Magnesium and Sodium were the most dominant cations than calcium and potassium. The cations content of the water samples increased during summer season. During 2021, the similar results were obtained. The cations were more during the summer and winter than southwest and north east monsoon seasons.

4.6 Anions

Anions like carbonate, bicarbonate, chloride and sulphate were analysed in the water samples. Most of the samples recorded slightly increase in the anions content during summer and winter when compared to monsoon seasons. This is directly correlated with the water table depth in the bore well and rainfall pattern and distribution. During 2021, the similar results were obtained. The anions were more during the summer and winter than southwest and north east monsoon seasons.

4.7 Carbonates

Carbonates varied from 0.30 to 3.5 m.e L^{-1}, 0.0 to 4.0 m.e L^{-1}, 0.0 to 4.2 m.e L^{-1} and 0.2 to 4.5 m.e L^{-1} during south west, north east, winter and summer seasons of 2020-2021, respectively. Most modern, and probably most ancient, carbonates are predominantly shallow water (depths <10-20 m) deposits. This is because the organisms that produce carbonate are either photosynthetic or require the presence of photosynthetic organisms.

4.8 Bicarbonates

Bicarbonates found to dominate and it ranged from 0.80 to 12.80 m.e L^{-1},

1.6 to12.8 m.e L^{-1}, 2 to 10 m.e L^{-1} and 2 to 11.6 m.e L^{-1} during south west, north east, winter and summer seasons of 2020-2021, respectively. The main sources of bicarbonates in the ground water are of carbonaceous rocks, which dissolve in water to give bicarbonate. The common rocks of carbonates include calcite and dolomite and calcites (Kahlown et al., 2006).

4.9 Chloride

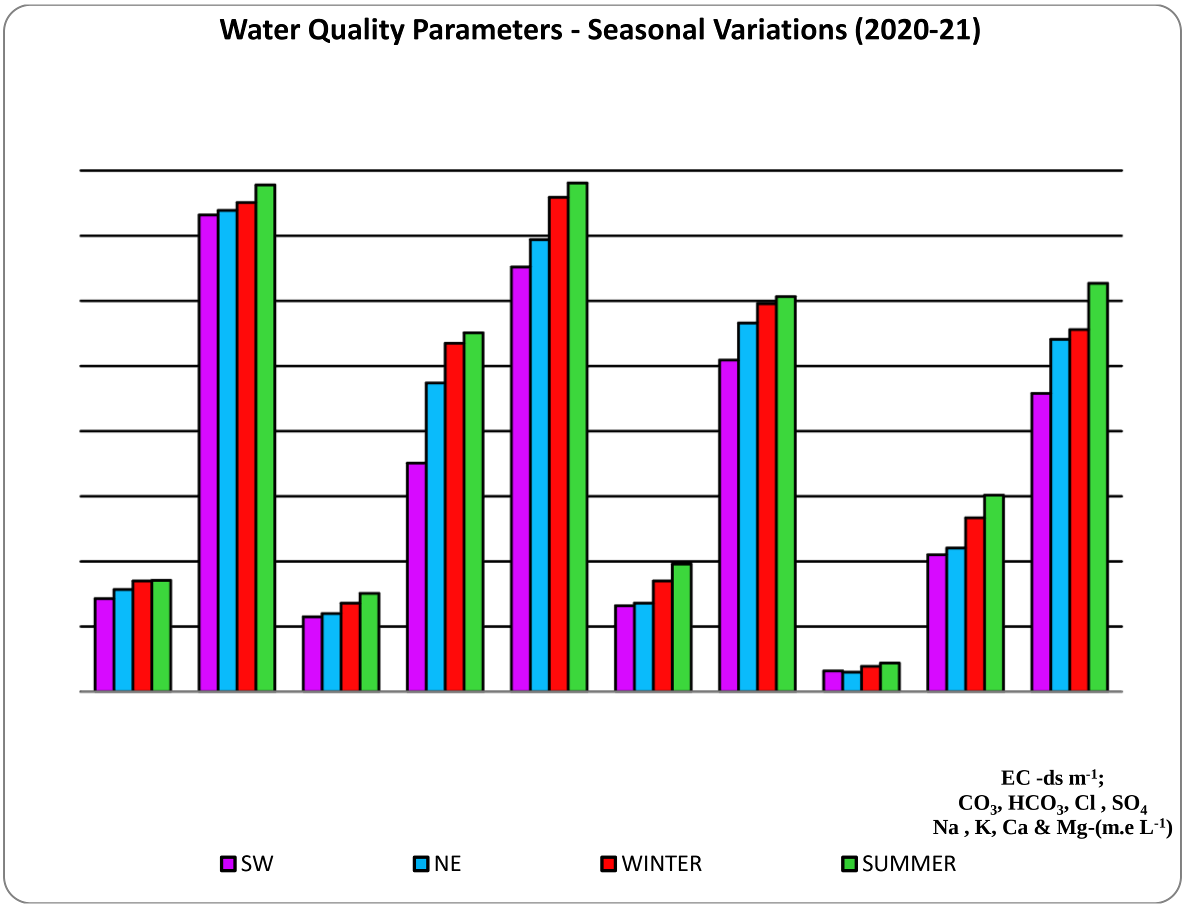
Chloride concentration in irrigation water is classified as excellent (<5 m.e L^{-1}) Good (5-10 m.e L^{-1}) and injurious (>10 m.e L^{-1}). Most of the samples (54 % during SW, 43 % during NE, 49 % during winter and 34 % during summer (2021) come under excellent category. Chloride was the most dominant anion during all the four seasons. If the water with high chloride is used for construction purpose, this may corrode the concrete. The highest concentration of chloride is due to the intrusion of sewage water into the river. High chloride content may harm metallic pipes and structures as well as growing plants. It will not develop any adverse effect once the human system becomes adapted to the water. The sewage is a rich source of chloride, a high value at all sampling periods indicating pollution of water by a sewage effluent. On the day of sampling, rain was over there. Hence runoff water into the river might be contributing to chloride concentration in the river. Most of the samples recorded slightly increase in the anions content during summer and winter when compared to monsoon seasons. This is directly correlated with the water table depth in the bore well and rainfall pattern and distribution. During 2021, the similar results were obtained. The anions were more during the summer and winter than southwest and north east monsoon seasons.

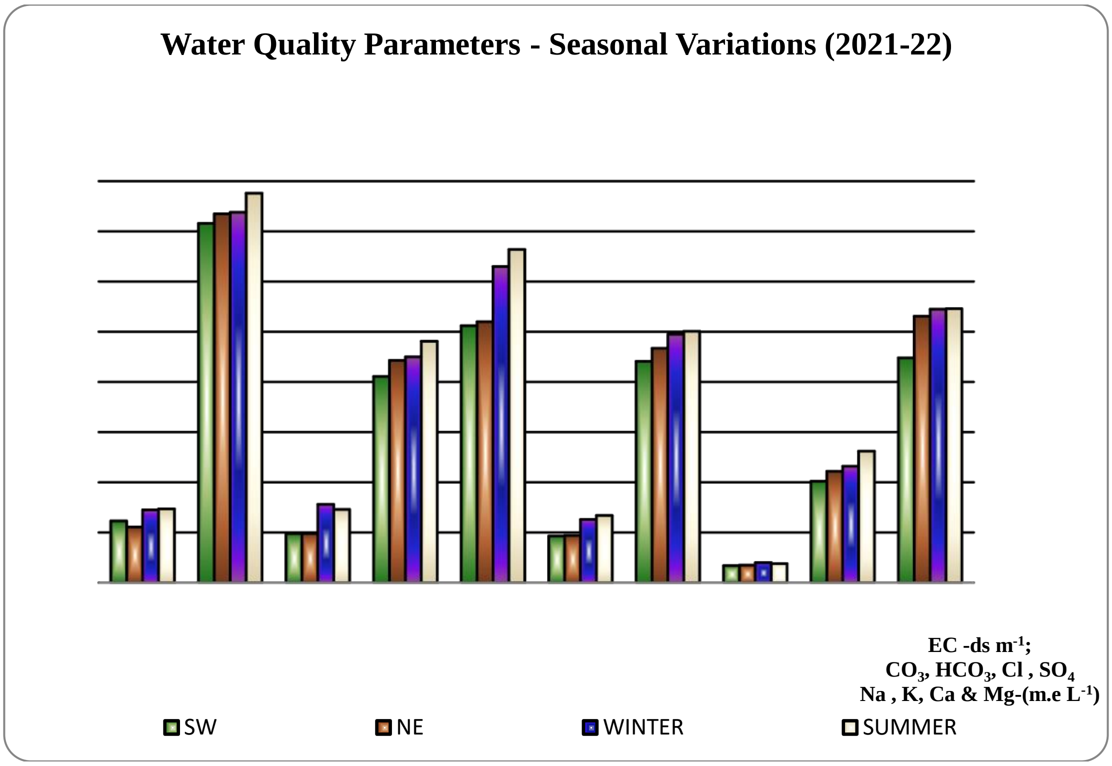
4.10 Total Hardness

Hardness is an indication of the amount of calcium and magnesium in the water and is expressed as m.eq of $CaCO_3$ L^{-1}, or parts per million $CaCO_3$. The amounts of these two elements in irrigation water are variable. Hardness is the measure of the capacity of water to react with soap to form lather. It is determined by the concentration of calcium and magnesium ions present in water. Total Hardness (as $CaCO_3$) levels between 200 mg / l to 600 mg / l are considered being acceptable. Water with hardness in the range of 100 to 150 mg $CaCO_3$ L^{-1} is considered desirable for plant growth. Plants tolerate high levels of these elements, so toxicity is not normally a problem. However, excessive hardness may cause foliar deposits of calcium or magnesium carbonate under overhead irrigation. Soft water (<50 mg $CaCO_3$ l^{-1}) may need additional calcium and or magnesium over and above that supplied by typical fertilizers to achieve good plant growth. The high concentration of hardness was recorded due to the intrusion of sewage, pseudo hardness by utilization of soap for washing (Gupta and Sahara, 2009). It denotes that the water is slightly and moderately hard. The high concentration of hardness above 350 mg/L indicates that the water is excessively hard. The hard water is useful to growth of children due to the presence of Ca^{2+} and Mg^{2+}. Moderately hard water is preferred to soft water for irrigation purpose. Cardiovascular diseases are reported in soft water areas (Jurgen, 1991). The permissible limit of hardness is 300 mg / l as per the IS 10500:1991. Total hardness in the study area varied from 9.6 to 83.8 m.e L^{-1} during SW, 10.9 to 112.6 m.e L^{-1} during NE, 6.3 to 112.9 m.e L^{-1} during winter. Micro nutrients and heavy metals contents in all the 35 water samples collected during the 2020 were with in the critical limit. Among the heavy metals, lead was not found in the water samples. This may be because of the sewage disposal and the discharge of industrial effluents into the river.

4.11 Residual Sodium Carbonate (RSC) and Residual Sodium bi Carbonate (RSBC)

RSBC was calculated as HCO3 – Ca and classified as satisfactory (< 5 me L-1), marginal (5- 10 me L-1) and unsatisfactory (> 10 me L-1) as per Gupta, (1983).Most of the samples are coming under safe category (86 % during SW, 82.0 % during NE, 72 % during winter and 72 % during summer). Similarly RSBC ranged from -1.40 to 10.2 meL^{-1} during SW, -1.00 to 10.0 meL^{-1} during NE, -0.5 to 8.10 meL^{-1} during winter and -1.00to 9.40 meL^{-1} during summer. RSBC values are classified as safe (<5.0), moderate (5.0 – 10.0) and unsafe (>10.0) based on total hardness. Most of the samples are coming under safe category (86 % during SW, 82 % during NE, 72 % during winter and 72 % during summer). Compared to 2020-2021 periods, the water quality parameter such as EC, pH, anions and cation contents were decreased during 2021-2022 due the decrease in the rainfall during the period (Fig. 4).





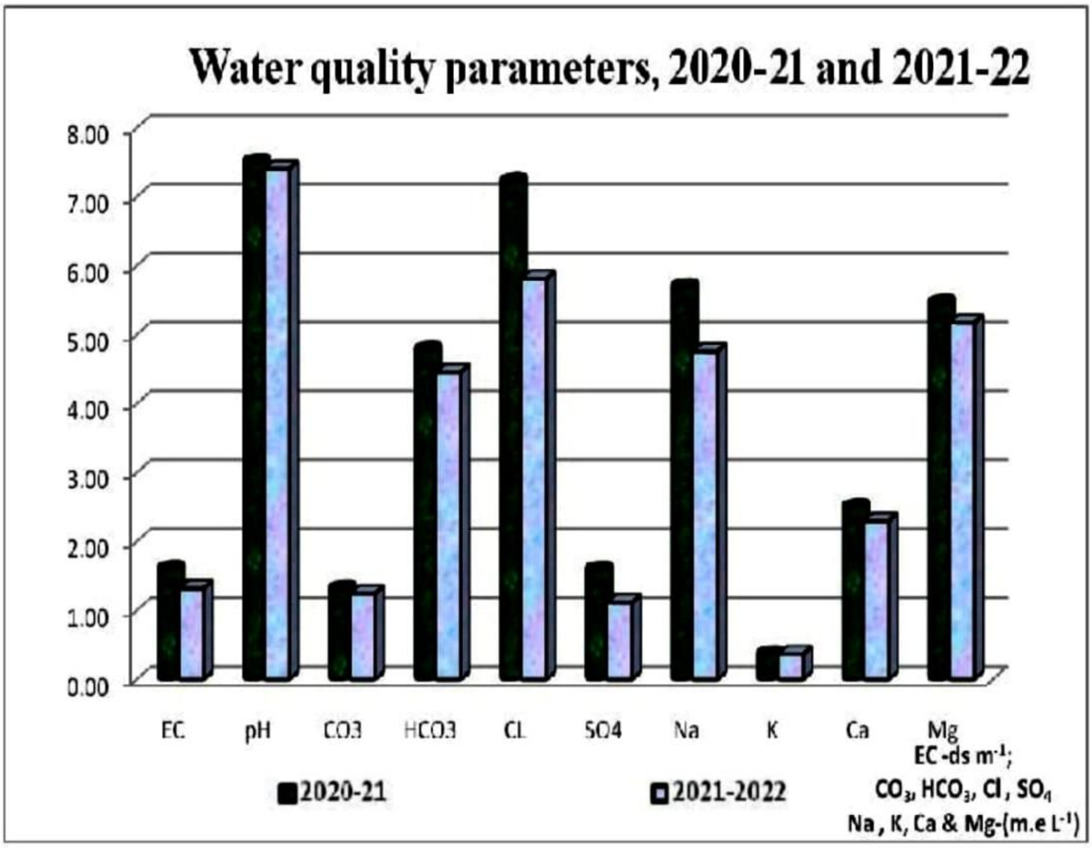


Fig. 4. Water quality parameters during different seasons of 2020 and 2021 (mean of 35 samples)

5. ANALYSIS AND INTERPERTATION

The two years data for the 35 samples were analysed using data analysis software and results were obtained and given in the Tables 1 and 2. The means value of EC during 2020-2021 was 1.43, 1.57, 1.70 and 1.71 dS m^{-1}, respectively at SW, NE, winter and summer seasons. The maximum EC value of 1.71 dS m^{-1} was recorded at summer season. Among the four seasons the lowest EC was recorded at SW monsoon. The results of the water samples showed that, the gradual increase in the pH was observed during the four seasons. It was ranged from 7.32 to 7.78. The highest pH was recorded at summer season (7.78) and lowest pH was recorded at SW monsoon (7.32). Anions like CO_3, HCO_3, Cl and SO_4 content was analysed in water samples during 2020. Of the four seasons tested for CO_3, the lowest value was recorded at the samples collected from SW monsoon period (1.15 m.e L^{-1}). The highest value of 1.51 m.e L^{-1} was observed at summer seasons. The CO_3 content of the water samples of four seasons ranged from 1.15 to 1.51 m.e L^{-1}. The mean HCO_3 content of water samples during 2020-2021 ranged from 3.51 to 5.51 m.e L^{-1}. The gradual increase in HCO_3 content was noticed up to summer season. The maximum and minimum HCO_3 content of 3.51 and 5.51 m.e L^{-1}, respectively was recorded at 2020-2021. The data on chloride content revealed that, it was higher at summer seasons. During 2020-2021 periods, the maximum sulphate content was observed at summer season (1.96 m.e L^{-1}) and the minimum was observed during the monsoon seasons.

All the major cations like Na, K, Ca and Mg were present in the water samples. the maximum Na, K, Ca and Mg content of 6.07, 0.44, 3.02 and 6.28 m.e L^{-1}, respectively was observed at SW, NE, winter and summer seasons. Regarding K content the lowest and highest content of 0.32 and 0.44 m.e L^{-1} was observed at SW and summer, respectively. The least Ca and Mg content of 2.10 m.e L^{-1} was recorded at SW monsoon (Table 1)

Similar to 2020, in 2021 also among the four seasons of water sample analysis, the highest EC of 1.47 dS m^{-1} was recorded at summer season, the slight reduction in EC value was observed at NE monsoon. Compared to all the four seasons, NE monsoon recorded the lowest EC. The pH of the water samples were analysed and the results shows that, the pH value of four seasons were 7.16, 7.35, 7.38 and 7.76, respectively during SW, NE, winter and summer. The highest and lowest pH of 7.76 and 7.16, respectively during summer and SW monsoon [9].

The various anions like, CO_3, HCO_3, Cl and SO_4 content of the water samples were analyses during 2021-2022. The CO_3 content of four seasons were 0.98, 0.98, 1.56 and 1.46 m.e L^{-1}, respectively during SW, NE, winter and summer. The maximum HCO3 content was observed at summer season (4.81 m.e L^{-1}). In case of chloride content of the water samples ranged from 5.12 m.e L^{-1} to 6.64 m.e L^{-1}. The maximum (6.64 m.e L^{-1}) and minimum (5.12 m.e L^{-1}) chloride content was recorded at summer and SW monsoon season, respectively. The maximum sulphate content of 1.34 m.e L^{-1} was observed at summer season. The cations (Na, K, Ca and Mg) content in the water samples were analyses and the results shows that, the maximum cations content of 5.02, 0.38, 2.62 and 5.47 m.e L^{-1} of Na, K, Ca and Mg was recorded respectively at SW, NE, winter and summer. The minimum concentration (4.41, 0.34, 2.02 and 4.48 m.e L^{-1}) observed at SW, NE, winter and summer season. The gradual increase in cation content were observes from SW monsoon season to summer season (Table 2). Compared to 2020-2021 periods, the water quality parameter such as EC, pH, anions and cation contents were decreased during 2021-2022. All the interpretations were directly related to water table depth, water level and rainfall pattern in the basin [10].

5.1 Rainfall Pattern, Groundwater Fluctuation and Water Quality Status

The rate and level of recharge depends upon the geological, geomorphological and soil conditions in the particular area. So comparison is also made between rainfall and ground water level. The rise in groundwater level is a direct consequence of precipitation, particularly in the monsoon season. The rise of water level at a particular place is characteristic feature of unsaturated zone. There exists a definite relationship between the amount of rise in water level and precipitation for a particular region. To study this relationship in PAP basin, the water level and rainfall data were collected and used. The rainfall distribution in the study area is not uniform due to the presence of hills in the study area and the changes in the topography and ground surface elevation. It depends upon spatial and temporal variations. The study area

Table 1. Water quality parameters during different seasons of 2020 (mean of 35 samples)

Parameter	Mean				Range				SD			
Seasons	**SW**	**NE**	**Winter**	**Summer**	**SW**	**NE**	**Win ter**	**Summer**	**SW**	**NE**	**Winter**	**Summer**
EC	1.43	1.57	1.70	1.71	4.89	6.51	6.54	3.53	1.09	1.23	1.23	0.86
pH	7.32	7.39	7.51	7.78	1.60	1.80	1.10	1.35	0.34	0.41	0.26	0.33
CO_3	1.15	1.2	1.36	1.51	3.20	3.20	4.00	4.00	0.81	0.81	0.86	1.10
HCO_3	3.51	4.74	5.35	5.51	12.0	11.2	8.00	9.60	2.37	2.15	2.02	2.13
Cl	6.52	6.94	7.59	7.81	35.2	44.0	44.0	44.4	6.78	7.70	8.17	7.76
SO_4	1.32	1.36	1.70	1.96	7.29	7.95	7.21	6.88	2.20	2.29	2.19	2.08
Na	5.09	5.66	5.96	6.07	14.4	19.4	21.6	16.1	3.39	4.64	5.66	4.15
K	0.32	0.30	0.39	0.44	2.42	1.04	1.00	1.50	0.45	0.29	0.29	0.40
Ca	2.10	2.21	2.67	3.02	4.48	4.56	4.56	9.28	1.24	1.41	1.39	1.93
Mg	4.58	5.41	5.56	6.28	18.1	24.8	26.0	25.6	3.40	4.42	4.45	4.38

SW: South West Monsoon; NE- North East Monsoon ;
Units-EC- ds m^{-1}, CO_3, HCO_3, Cl, SO_4, Na, K, Ca & Mg - m.e L^{-1}

Table 2. Water quality parameters during different seasons of 2021 (mean of 35 samples)

Parameter	Mean				Range				SD			
Seasons	**SW**	**NE**	**Winter**	**Summer**	**SW**	**NE**	**Win ter**	**Summer**	**SW**	**NE**	**Winter**	**Summer**
EC	1.23	1.11	1.45	1.47	4.61	5.31	3.5	3.13	0.90	1.05	0.92	0.78
pH	7.16	7.35	7.38	7.76	1.62	1.22	1.71	1.29	0.32	0.26	0.41	0.25
CO_3	0.98	0.98	1.56	1.46	3.2	4.0	4.2	4.30	0.63	0.79	1.00	0.98
HCO_3	4.11	4.43	4.50	4.81	14.2	15.3	6.4	8.20	2.77	3.21	1.72	1.99
Cl	5.12	5.20	6.31	6.64	18.8	20.4	14.8	15.2	3.65	4.17	4.39	4.57
SO_4	0.93	0.94	1.26	1.34	6.68	6.83	6.88	7.05	1.53	1.55	1.96	2.04
Na	4.41	4.67	4.95	5.02	11.6	11.6	13.8	14.6	2.86	2.88	3.62	3.73
K	0.34	0.35	0.40	0.38	1.28	1.35	1.09	2.00	0.35	0.36	0.27	0.38
Ca	2.02	2.22	2.32	2.62	2.30	2.30	2.30	2.30	0.62	0.62	0.62	0.62
Mg	4.48	5.31	5.46	5.46	18.1	24.8	26.0	12.6	3.40	4.42	4.45	2.72

SW: South West Monsoon; NE- North East Monsoon ;
Units-EC- ds m^{-1}, CO_3, HCO_3, Cl, SO_4, Na, K, Ca & Mg - m.e L^{-1}

Table 3. Water table depth (Open well (m), Bore well (Feet), Bore well water level (feet)) in PAP basin (average value)

S.No.	SW			NE			Winter			Summer		
	Open well	Bore well	BW water level	Open well	Bore well	BW water level	Open well	Bore well	BW water level	Open well	Bore well	BW water level
1	12.6	410	110	13.4	410	115	11.9	410	104	11.3	410	98
2	12.0	402	102	17.0	402	107	15.5	402	96	14.9	402	90
3	12.0	415	115	12.3	415	120	10.8	415	109	10.2	415	103
4	7.5	450	150	8.0	450	155	6.5	450	144	5.9	450	138
5	9.0	465	165	8.5	465	170	7.0	465	159	6.4	465	153
6	10.5	410	110	9.9	410	115	8.4	410	104	7.8	410	98
7	9.6	450	150	9.7	450	155	8.2	450	144	7.6	450	138
8	10.8	460	160	15.3	460	165	13.8	460	154	13.2	460	148
9	8.1	475	175	8.6	475	180	7.1	475	169	6.5	475	163
10	9.0	485	185	9.6	485	190	8.1	485	179	7.5	485	173
11	9.6	420	120	9.9	420	125	8.4	420	114	7.8	420	108
12	4.8	435	135	6.3	435	140	4.8	435	129	4.2	435	123
13	3.0	415	115	8.1	415	120	6.6	415	109	6	415	103
14	5.1	465	165	4.5	465	170	3.0	465	159	2.4	465	153
15	12.9	470	170	18.3	470	175	16.8	470	164	16.2	470	158
16	11.4	490	190	11.7	490	195	10.2	490	184	9.6	490	178
17	10.5	415	115	11.2	415	120	9.7	415	109	9.1	415	103
18	8.7	425	125	7.7	425	130	6.2	425	119	5.6	425	113
19	10.2	405	105	9.4	405	110	7.9	405	99	7.3	405	93
20	11.1	415	115	11.4	415	120	9.9	415	109	9.3	415	103
21	9.0	430	130	12.8	430	135	11.3	430	124	10.7	430	118
22	10.2	440	140	10.8	440	145	9.3	440	134	8.7	440	128
23	8.7	455	155	7.7	455	160	6.2	455	149	5.6	455	143
24	8.1	460	150	7.4	460	155	5.9	460	144	5.3	460	138
25	9.9	415	110	10.2	415	115	8.7	415	104	8.1	415	98
26	10.2	465	150	14.5	465	155	13	465	144	12.4	465	138
27	4.8	490	140	5.1	490	145	3.6	490	134	3	490	128
28	5.7	485	150	5.8	485	155	4.3	485	144	3.7	485	138
29	7.2	480	135	7.4	480	140	5.9	480	129	5.3	480	123

S.No.	SW			NE			Winter			Summer		
	Open well	**Bore well**	**BW water level**	**Open well**	**Bore well**	**BW water level**	**Open well**	**Bore well**	**BW water level**	**Open well**	**Bore well**	**BW water level**
30	10.5	465	140	9.7	465	145	8.2	465	134	7.6	465	128
31	8.7	470	130	7.7	470	135	6.2	470	124	5.6	470	118
32	7.8	475	155	8.3	475	160	6.8	475	149	6.2	475	143
33	9.6	490	150	9.9	490	155	8.4	490	144	7.8	490	138
34	11.1	480	165	11.4	480	170	9.9	480	159	9.3	480	153
35	8.7	450	145	8.0	450	150	6.5	450	139	5.9	450	133

experiences four seasons namely, Winter season(January & February),Summer season(March, April and May),South west monsoon (June,July,August and September and North East Monsoon(October, November and December). More rainfall occurred in the last two seasons of the each year. The rainfall occurs due to north east as well as south west monsoons. But the percentage of rainfall occurring due to north east monsoon is more than south west monsoon [11].

The study area is supplied with irrigation water through Pollachi main canal, whose length is 48 kms with 30 distributories, divided into two zones receiving water once in alternate years. So the farmers have to inevitably depend on groundwater during non supply period and also during supply period in deficit years of monsoon. There are large number of bore wells and open wells in the area. Hence it is necessary to study the groundwater utilization and its impact in long run. An accurate estimation of the spatial and temporal fluctuation of a water table is of prime importance in the management of groundwater resources. Groundwater recharge in hard rock areas is by monsoon rains only. The water table will be lowest in the beginning of the monsoon (May), attains highest level at the end of monsoon (Nov-Dec) and recedes thereafter during the non-monsoon period. The response of groundwater depends on many factors such as initial groundwater level, intensity and distribution of rainfall, drainage pattern of the watershed, vegetation, and water withdrawal pattern for irrigation purpose etc [12].

The rainfall distribution in the study area is not uniform due to the presence of hills and the changes in the topography. The entire PAP basin is influenced by 4 rain gauge stations in plain area and 11raingauge stations in hilly areas. There is a significant rise in water levels due to rainfall in the months of July, October and November. Total amount of rainfall received in the study area during 2020 was 628.7 mm. Rainfall amounts recorded in the study area revealed that there is no rainfall in January, February and March. During April, June, July and August rainfall amounts of less than 50 mm was recorded. About 64.5mm rainfall was recorded during the summer (May). The maximum rainfall of 150.5mm was recorded during the month November. Minimum rainfall occurs during April was 30.5mm. During 2020, there was no rainfall during winter, 15% rainfall occurs during summer, 35% of rainfall occurred during South West monsoon and maximum amount of rainfall 50% occurs during Northeast monsoon.

Total amount of rainfall received in the study area during 2021 was 783 mm. There is no rainfall in January, and July. During February, March, May, June, August and September rainfall amounts of less than 50 mm was recorded. About 33mm rainfall was recorded during the summer (May). The maximum rainfall of 256mm was recorded during the month October .Minimum rainfall occurs during February was 7mm. During 2021, there was rainfall during winter 1%, 18% rainfall occurs during summer, 9% of rainfall occurred during South West monsoon and maximum amount of rainfall 72% occurs during Northeast monsoon. In the study area, the data of water quality and water table of 35 observation wells between 2020 and 2022 was taken for consideration .

5.2 Mapping using RS and GIS

The latitude/longitude details of observation wells in PAP basin are taken using GPS and with the latitude/longitude details of observation wells, the quality map for the ground water status of PAP basin was prepared using ARC GIS software. The Electrical Conductivity (EC) values at different seasons of 2020 and 2021 were taken and quality map for the salinity was prepared (Figs. 5 and 6).

Electrical conductivity values were ranged from 0.3 to 5.19 dsm^{-1}, 0.29 to 6.80 dsm^{-1} 0.3 to 6.84 dsm^{-1} and 0.64 to 4.17 dsm^{-1} during south west, north east, winter and summer seasons of 2020-2021, respectively. The samples were classified under USSL classification. Most of the samples come under high salinity class (C_3) (57, 74, 77 & 80 %), followed by very high salinity class (C_4) (14, 11, 17 & 17 %) medium salinity class (C_2) (29, 15, 6 & 3 %) during the four seasons of 2020-2021, respectively. The salt content was slightly increased during winter and summers seasons as compared to south west and north east [13].

Electrical conductivity values ranged from 0.09 to 4.7 dSm^{-1}, 0.02 to 5.33 dSm^{-1}, 0.34 to 3.84 dSm^{-1} and 0.48 to 3.61 dSm^{-1} during south west, north east, winter and summer respectively. The samples were classified according to USSL classification. Most of the samples come under high salinity class (C_3) (57, 37, 63 & 69 %), followed by very high salinity class (C_4) (11, 14, 17 & 17 %) medium salinity class (C_2) (23, 37, 20 & 14 %) during the four seasons of 2020-2021, respectively. Most of the samples come under high salinity class (C_3) followed by medium salinity class (C_2), very high salinity class (C_4), low salinity class (C_1) during south west, north east, winter and summer.

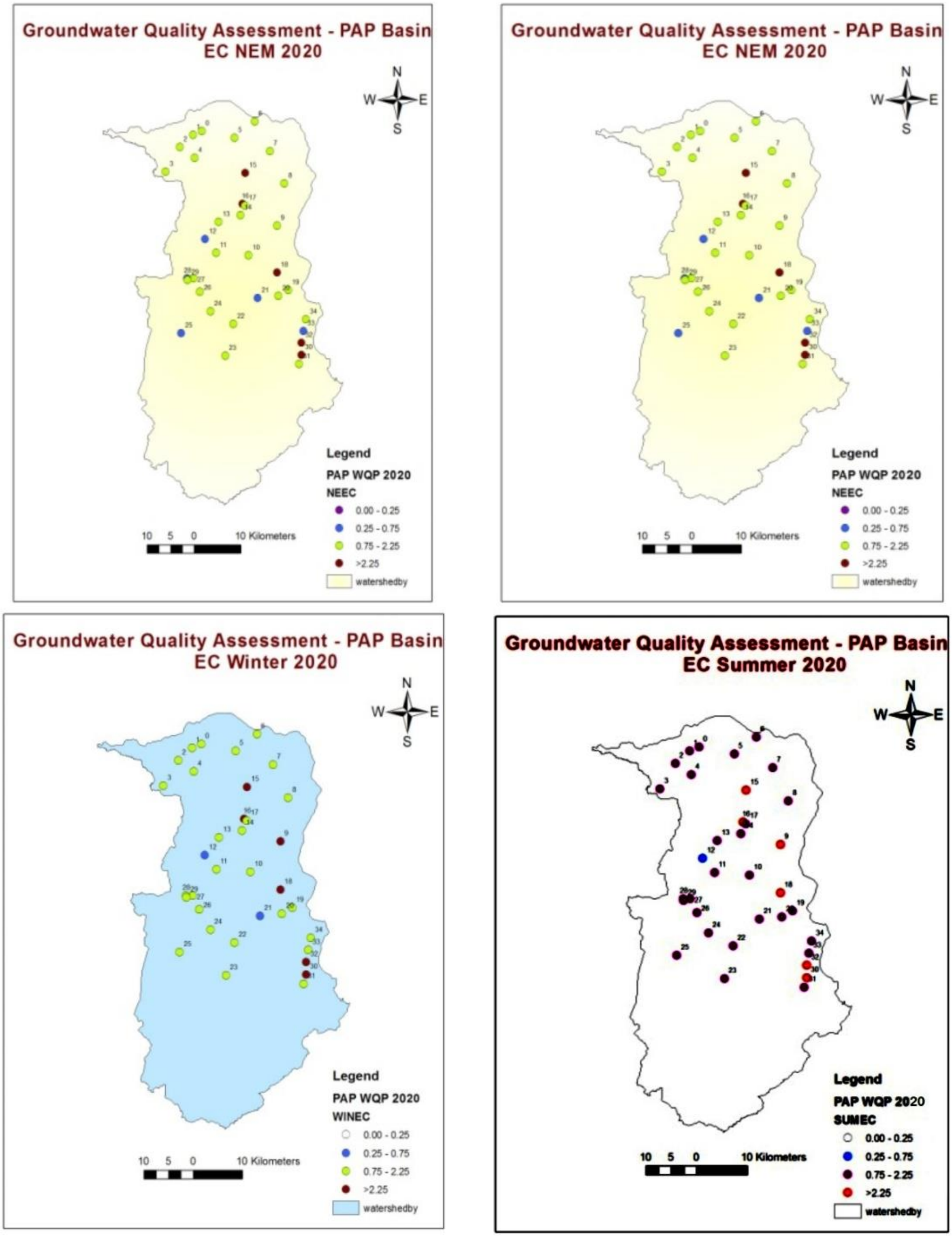


Fig 5. EC value in the groundwater samples of pap basin in various seasons of 2020

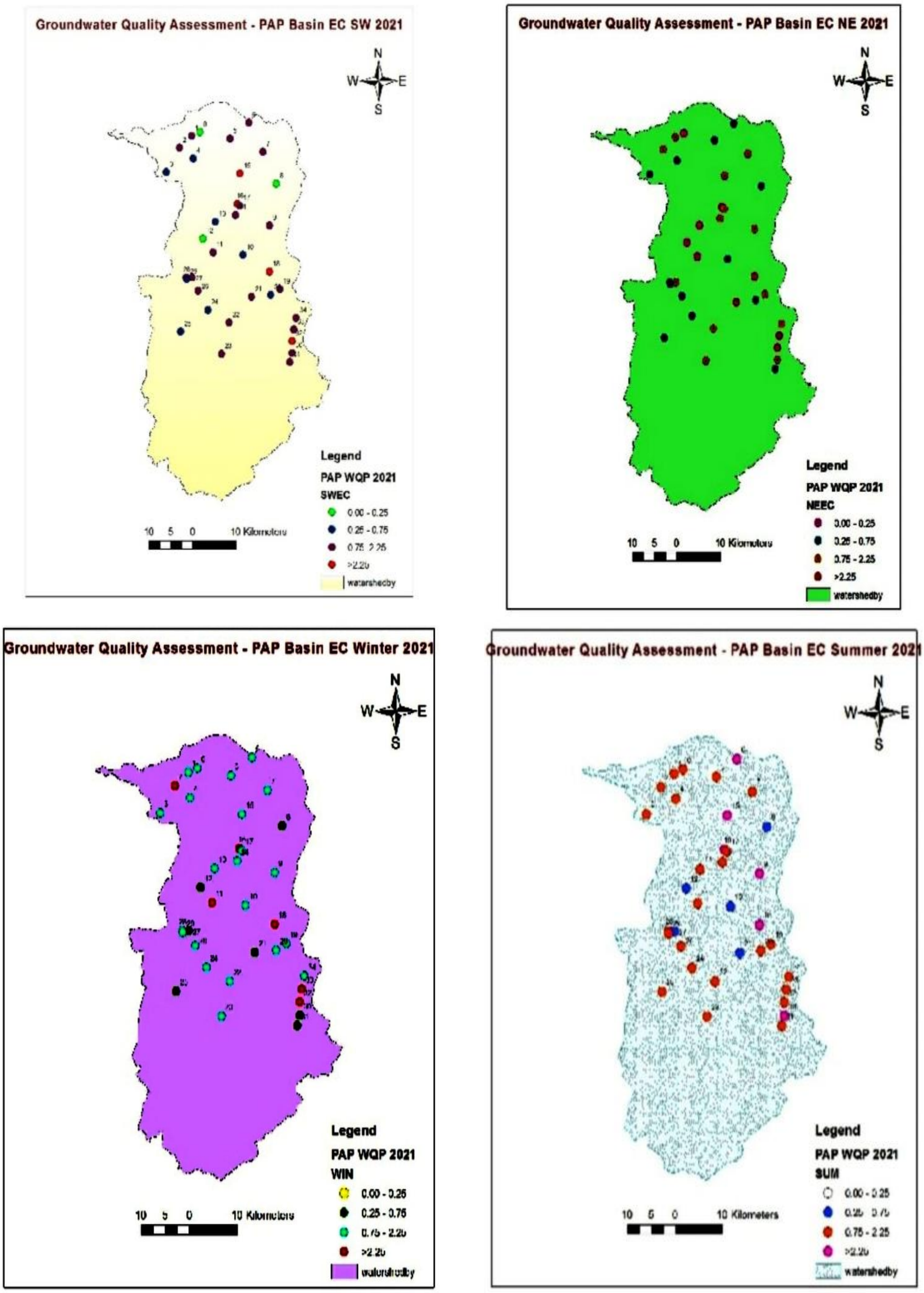


Fig. 6. EC value in the groundwater samples of pap basin in various seasons of 2021

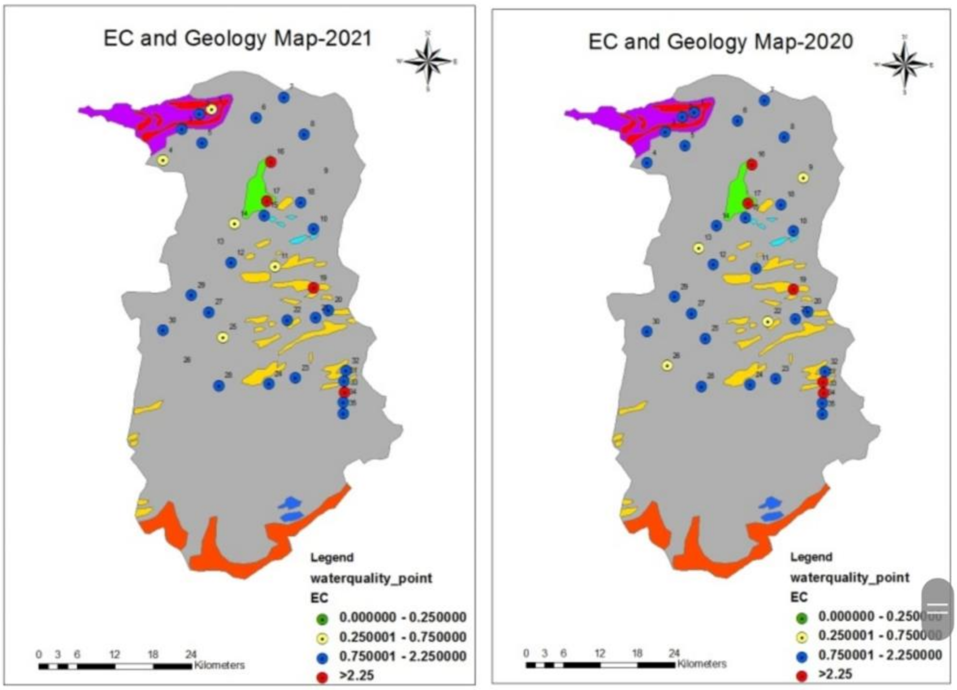


Fig. 7. EC in the ground water samples with geology (2020 and 2021)

The geology of the PAP basin was correlated and super imposed with quality of the ground water using GIS technique (Fig. 7).

6. CONCLUSION

Present study is to assess the groundwater quality in this basin. The increase in ground water levels and water quality mainly depends on the rainfall and recharge of ground water. Decrease in the ground water level in some of the observation wells are mainly due to over exploitation of ground water, and reduction in rainfall. When compared to summer, the post monsoon water sampling indicates that most of the samples cations like sodium, potassium, calcium and magnesium were reduced and the anions like carbonate, bicarbonate, chloride and sulphate were also reduced. The increase or decrease in the salt content of the water samples are positively correlated with the water table / level of the open or bore wells. Micro nutrients and heavy metals contents in all the 35 water samples collected during the 2020 and 2021 were within the critical limit. Some of the branch canals and distributaries remain dry for a long period except during supply through them [14]. Hence the ground water recharge in these areas is not possible. Moreover the ground water is also extracted for agriculture purpose during non irrigation period by the farmers. Hence the groundwater depletion is more in these areas. The management strategies such as growing of salt tolerant crops and varieties, conjunctive use of saline and good quality water, drip irrigation, gypsum treatment, judicious use of organic manures, ridge and furrow method of sowing etc maybe followed for the amelioration of groundwater quality in the basin [15-20].

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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