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Research Article

Geochemical Studies of Groundwater in HebbahallaWatershed, Mysore District, Karnataka, India

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Abstract

Geochemical studies were conducted to find out the variation of chemical studies in Hebbahalla watershed. The groundwater sample collected from fifty-bore wells sample in different locations for pre and post monsoon season. As the groundwater quality varies from one season to another season, it is necessary to measure the spatial distribution and variation between the seasons, so the sample data have been collected during pre and post monsoon season in the year of 2013. The result of each parameters have been linked with the GPS location data in the Geographical Information System (GIS) to find out the spatial distribution and variation of groundwater and interpolation technique named Inverse Distance Weighed(IWD) in ArcGIS has been used based on fifty sample results. The chemical components of parameters such as Na, Ca, K, Mg, Cl, HCO_3, SO_4, NO_3, EC, TDS, P^H.

Key words: *Groundwater, GIS, Spatial variation, SAR, Hebbahalla watershed*

1. Introduction

The study of groundwater involves both geological as well as chemical aspects, which play a larger role, because of its importance in characterization of natural system, understanding contaminant migration and designing remedial programmes, hydrogeochemistry deals with the transformation and transportation of substances, along with circulation of water in the chemical areas of the globe. Groundwater contains a variety of chemical composition at different concentrations. The groundwater comes from soluble minerals in soils and sedimentary rocks (Water watch, 2005). A much smaller part has its origin in the atmosphere and surface water bodies. For most of the groundwater, 95% of the ions are represented by a few major ionic species: the positively charged cations sodium (Na^+), potassium (K^+), calcium (Ca^{2+}) and magnesium (Mg^{2+}), and the negatively charged anions chloride (Cl^-), sulfate (SO_4^{2-}), bicarbonate (HCO_3^-) and nitrate (NO_3^-). These ionic species when added together account for most of the salinity that is commonly referred to as total mineralisation or total dissolved solids (TDS).

1.1 Purpose of the study area

1. To understanding of the evolution of the groundwater chemistry, and possible causes for groundwater quality change
2. To evaluation of baseline groundwater quality and the relevant beneficial uses of the groundwater resource
3. To demarcate the various spatial distribution of groundwater in Hebbahalla watershed

1.2. Study area

The chemical analysis and quality of groundwater in Hebbahalla watershed area is H.D Kote and Hunsurtaluk, Mysore district, Karnataka, India. The total geographical area of the study area is 400 sq.kms. It is located between latitude 12^0 19’12’’ and 12^0 06’36ˈEˈand longitude 76^0 16’12’’ and $76^0$31’12’’ N covered under the Survey of India toposheet numbers are 57D/7, 57D/11, 57D/12 and 57D/8.

It has an average elevation of about 694mts. The area is bounded in north by Hunsurtaluk, in the south by Kodagu district, in the east by Nanjangud and Mysore taluk . The sample location of the study area is 50 bore well samples in Hebbahalla watershed **(Fig 1).**

1.3 Geology

The Hebbahalla watershed covers crystalline and high grade supracrustal rocks occurring as huge enclaves within hornblende-biotite gneiss, charnockite, quartzite and granite belong to Archean to lower Proterozoic, which include quartzite-pellite-carbonate association along with banded iron formations, magniferous horizons and amphibolites having dip $60^0$and strike N65^0E. Recent alluvium deposits are noticed.

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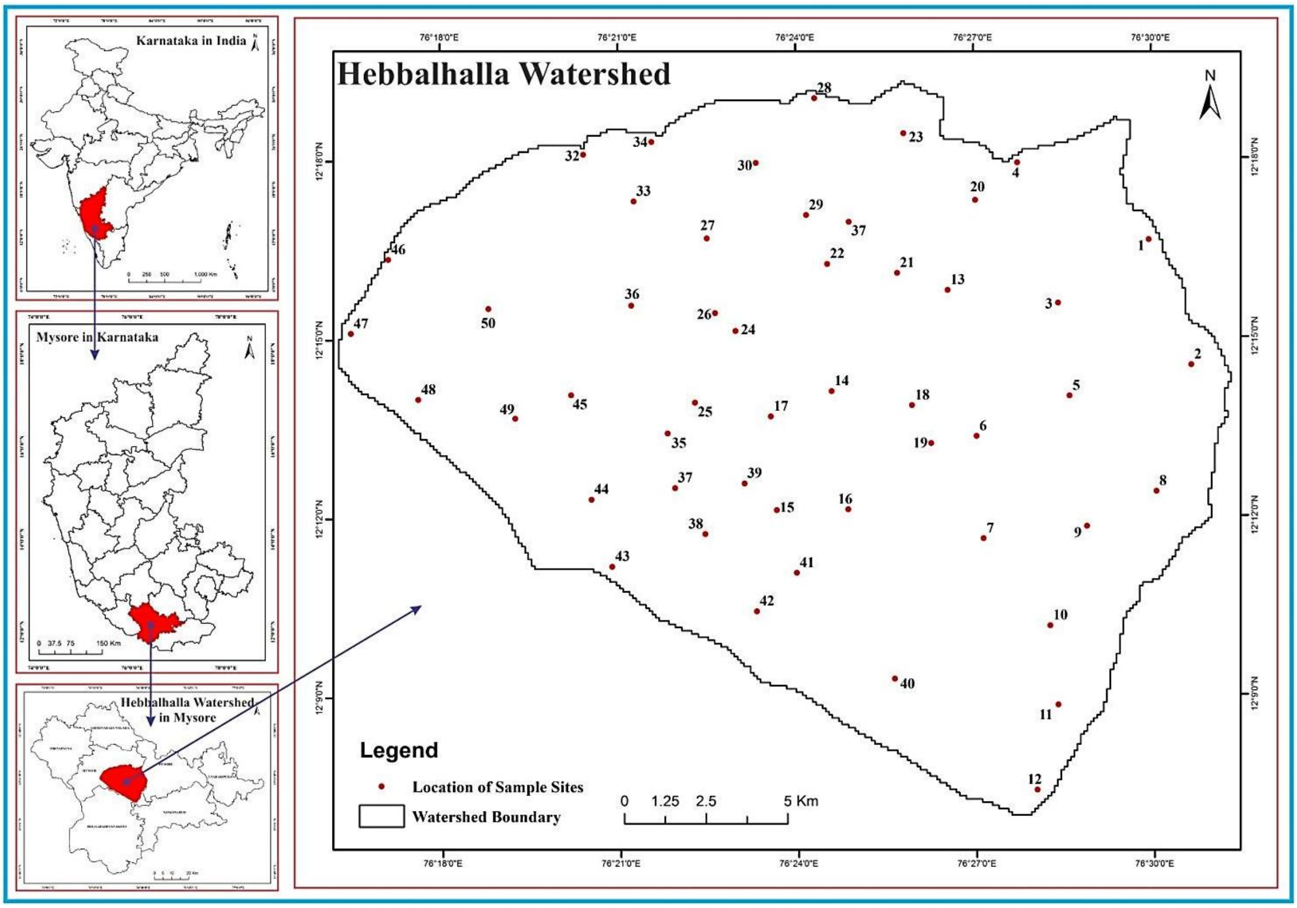


Fig.1 Location and Bore well Sample sites of the Study area

Table 1 Analytical results of chemical components of groundwater in Hebbahalla watershed (PPM)

Pre – Monsoon											
Location	**EC**	**pH**	**Ca**	**Mg**	**Na+K**	**HCO_3**	**CO_3**	**Cl**	**NO_3**	**SO_4**	**TDS**
1	1331	7.7	80	55	114	624	0	42	54	50	738
2	1850	7.71	107	128	126	815	0	161	125	76	1178
3	1743	7.5	84	93	143	760	0	112	66	35	979
4	1412	7.7	76	40	162	527	0	126	42	60	839
5	2112	7.45	84	165	76	845	0	182	69	49	1179
6	1324	7.8	100	75	49	710	0	28	39	10	718
7	2194	7.34	112	130	116	747	0	252	126	30	1210
8	1950	7.8	148	120	50	637	0	203	115	75	1133
9	2790	7.56	128	135	240	852	0	287	215	110	1635
10	2762	7.53	124	153	204	687	0	357	242	130	1638
11	2320	7.81	84	177	102	946	0	168	105	66	1235
12	1638	7.92	60	95	128	760	0	84	56	30	883
13	1345	7.41	106	48	99	647	0	73	8	33	722
14	1176	7.79	73	57	77	505	0	67	60	31	668
15	1039	7.31	101	40	49	471	0	45	46	33	579
16	3226	6.86	117	108	207	943	0	141	162	85	1848
17	936	6.5	99	34	38	372	0	56	61	35	539
18	1096	7.22	46	54	99	510	0	67	4	32	587
19	1072	7.36	85	46	64	456	0	50	44	55	602
20	972	7.14	58	48	68	480	0	25	40	25	534
21	999	6.86	64	59	46	480	0	20	70	22	551
22	1123	6.95	120	27	71	510	0	45	55	36	639
23	1025	7.03	80	45	61	495	0	36	38	25	562
24	1255	6.92	114	44	76	554	0	48	92	31	712
25	1134	6.9	99	42	69	519	0	64	20	35	619

26	924	7.09	69	45	49	426	0	39	39	26	420
27	1311	7.02	86	42	127	554	0	81	73	28	744
28	1301	6.7	86	66	79	441	0	118	88	51	738
29	1156	7.29	58	68	73	553	0	56	30	22	612
30	1130	7.09	67	50	89	559	0	25	45	35	620
31	1068	7.26	62	54	74	548	0	31	19	26	570
32	7790	7.73	76	135	71	744	0	105	92	62	943
33	1037	7.12	98	37	57	478	0	35	60	29	585
34	1344	7.25	112	72	48	536	0	77	97	45	749
35	1829	7.32	128	112	66	492	0	154	265	78	1079
36	1240	7.45	80	52	96	429	0	84	138	38	733
37	841	7.59	48	62	22	462	0	28	4	0	425
38	1314	7.46	56	70	107	661	0	42	40	24	699
39	1249	7.17	100	55	70	563	0	63	43	39	682
40	895	7.8	52	35	81	416	0	35	36	28	505
41	2318	7.52	68	144	184	808	0	224	170	43	1338
42	1235	7.35	100	75	29	537	0	70	55	34	661
43	2287	7.05	156	95	170	675	0	231	246	65	1401
44	956	7.57	96	32	50	404	0	56	55	24	545
45	766	7.94	76	35	24	393	0	28	7	17	417
46	1885	7.4	60	137	109	735	0	140	87	71	1002
47	2046	7.15	96	155	69	753	0	154	105	101	1157
48	1270	7.2	68	67	90	505	0	56	105	56	725
49	1272	7.18	64	42	142	612	0	56	42	22	704
50	1403	7.81	68	97	64	630	0	84	44	31	717

along the valley. The major lineaments /Fractures oriented along N-S, NW-SE, NNW-SSE and E-W directions.

2. Methodology

The water is precious and natural resources. For the groundwater study a proper methodology has been adopted to choose the ways and means for collection of data pertaining chemical component and groundwater quality. The groundwater has been considered as a main source for drinking water. Information on the groundwater quality is an important aspects any hydrological investigation. The groundwater samples were collected from 50 bore wells in both pre monsoon and postmonsoon (**Fig 1)**. The samples were pre-treated and analysed as per ISI standard methods. The EC, TDS, pH and major ions including Ca, Mg, Na, K, HCO_3, CO_3, Cl, NO_3 and SO_4 were determined **(Table 1).**The hdrogeochemical data have interpreted using the following methods in this study.

1. Classification of groundwater with respect to its Hardness, Salinity and Sodium Hazard based on Handa' classification (1965).
2. Identification of water types based on Scholler's method (1967).
3. $CaCO_3$ Saturation indices of groundwater using pH method (Hem, 1961; Handa, 1964) and equilibrium Ca method (Larsen and Boswell, 1942).
4. Identification of the mechanisms controlling chemistry of water using Gibb's plots (Gibb's1970). Sodium adsorption ratio, Residual sodium carbonate were determined.

The suitability of groundwater for different purposes is assessed based on the amount of Total Dissolved Solids (TDS). The dominant hydrochemicalfacies are correlated with the ion evolution sequence of Chebatorev (1955). The spatial distribution and changes of groundwater quality are assessed through graphical representations. Ionic ratios computed from ionic concentration expressed in 'epm' or 'r' values are calculated for classifying the water bodies. These hydrochemical parameters are useful for tracing the geochemical evolution of groundwater. Scholler's (1956) concept of water type is related the evolution of that groundwater with respect to chemistry. The data shows that the groundwater in the area is of I, II, III, and IV types, Where rCO3>rCl OR rSo4 is considered as type I, rSo4>rCl is considered as a II, rCl> rSO4 > rCO3 is considered as type III and r Cl>rSO4> rCO3 and r Na >rMg>rCa are considered as type IV. The predominance of chloride ion in certain areas reflects greater residence time of groundwater.

4. Results and Discussion

Various thematic maps are prepared to illustrate the spatial distribution of groundwater in the Hebbahalla watershed. The hydrochemical data plotted over the modified Hill Piper diagram of Handa (1965) is useful for characterizing the water types and to evaluate the suitability of water for domestic, industrial and irrigational purposes. In addition, this diagram also provides the geochemical modifications and evolution of water quality during its mobility in the subsurface systems.

4.1 Spatial Distribution and Changes of TDS

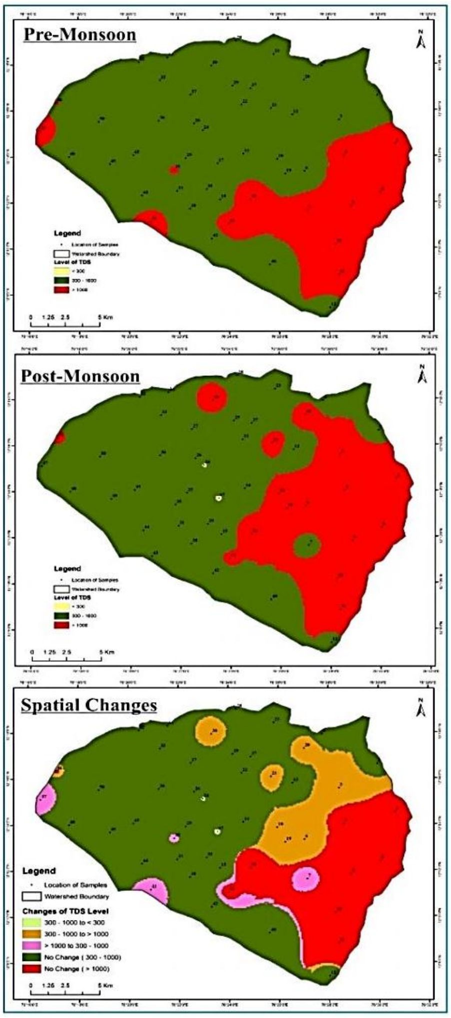
The temporal variations of the TDS value the results of pre and post monsoon have found using overlay method in Arc GIS 10.1 version. The result shows that, during the pre-monsoon no area comes under < 300 which is suitable for domestic use, and 290.23 km^2 areas have the value of 300 to 1000 which is suitable for irrigation. The area have > 1000 TDS value are 100.57 km^2 which is not suitable for domestic, industry or irrigation **(Fig 2).**

The spatial variation of post-monsoon result shows that 0.21 km^2 have value of < 300 TDS value which is suitable for domestic use and 253.78 km ^{2} have 300 – 1000 TDS value that can be used for irrigation purpose while 136.81 km^2 have the value of > 1000 which cannot be used for either domestic nor irrigation. The result of temporal changes between pre and post-monsoon shows that 86.84 km^2 of study area has the value of > 1000 which cannot be used for any purpose, and 13.73 km^{2}area have been changed from > 1000 to 300 – 1000 which depicts 13.73 km^2 area have changed from unsuitable for anything into the water which is suitable for irrigation. Then 0.21 km2 area have been changed from 300 – 1000 to < 300 which means the area which was having irrigation standard water quality have been changed into domestic standard. Finally, the rest of 240.05 km^2 area has value of 300 – 1000 during preand post-monsoon without any changes.

The overall study depicts that 49.97 km^2 (from 300 - 1000 to > 1000) areas water quality has been decreased while 13.93 km^2 areas (13.73 km^2 from > 1000 to 300 – 1000 and 0.21 km^1 from 300 – 1000 to < 300) have increased.

4.2 Specific Electrical Conductivity (EC)

The electrical conductivity is affected by temperature of water, the higher connectivity occurs when the water is warm, so the measurement of conductivity always reported at 25^{0}C, for the present study the result of electrical conductivity has been classified into four classes as <500, 500-700, 700-1000 and >1000. This classification is based on Wilcox's classification, which indicates the EC range at 25^{0}C below than 500 has excellent water quality, 500-700 EC range has good water quality, 700-1000 EC range has Permissible water quality and more than 1000 has doubtful water quality.

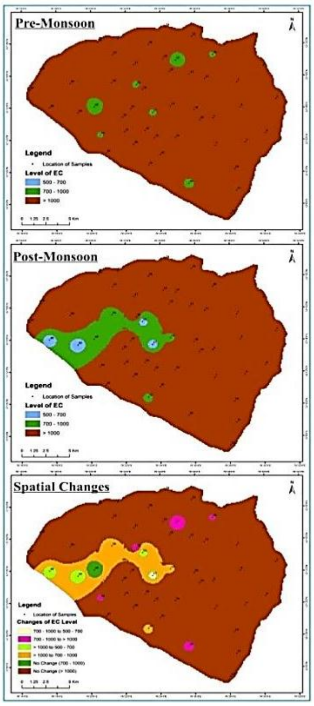


Distribution of TDS (Pre-Monsoon)			
Classes	No of Samples	Area (Sq. KM)	Area (%)
< 300	0	0	0
300 - 1000	37	290.23	74.27
> 1000	13	100.57	25.73
		390.8	100
Source: Generated by Researcher			

Distribution of TDS (Post-Monsoon)			
Classes	No of Samples	Area (Sq. KM)	Area (%)
< 300	2	0.21	0.05
300 - 1000	32	253.78	64.94
> 1000	16	136.81	35.01
		390.8	100
Source: Generated by Researcher			

TDS Changes from Pre to Post Monsoon		
Classes	Area in (Sq KM)	Area (%)
No Change (> 1000)	86.84	22.22
> 1000 to 300 - 1000	13.73	3.51
300 - 1000 to > 1000	49.97	12.79
300 - 1000 to < 300	0.21	0.05
No Change (300 - 1000)	240.05	61.43
	390.8	100
Source: Generated by Researcher		

Fig.2 Spatial Distribution and Changes of TDS in Hebbahalla watershed

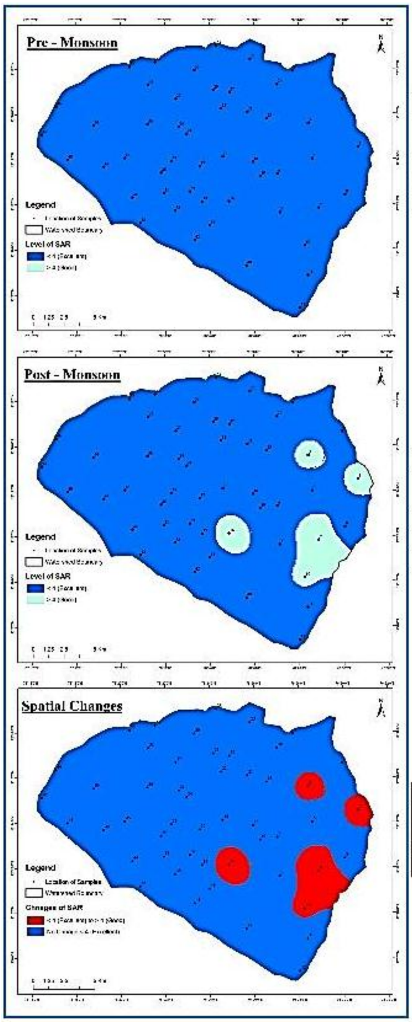


Distribution of EC (Pre-Monsoon)			
Classes	No of Samples	Area (Sq KM)	Area (%)
700 - 1000	8	7.16	1.83
> 1000	42	383.64	98.17
		390.8	100

Distribution of EC (Post-Monsoon)			
Classes	No of Samples	Area (Sq KM)	Area (%)
500 - 700	4	5.07	1.3
700 - 1000	4	39.11	10.01
> 1000	42	346.62	88.69
		390.8	100

EC Changes from Pre to Post Monsoon		
Classes	Area in (Sq KM)	Area %
> 1000 to 500 - 700	4.61	1.18
> 1000 to 700 - 1000	36.55	9.35
700 - 1000 to > 1000	4.14	1.06
700 - 1000 to 500 - 700	0.46	0.12
No Change (> 1000)	342.48	87.64
No Change (700 - 1000)	2.56	0.66
	390.8	100

Fig.3 Spatial Distribution and Changes of EC in Hebbahalla watershed



Distribution of SAR (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
< 4 (Excellent)	50	390.8	100
> 4 (Good)	0	0	0
		390.8	100

Distribution of SAR (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
< 4 (Excellent)	45	355.9	91.07
> 4 (Good)	5	34.9	8.93
		390.8	100

SAR Changes from Pre to Post Monsoon		
Changes	Area	Area in %
No Chnage < 4 (Excellent)	355.9	91.07
< 4 (Excellent) to > 4 (Good)	34.9	8.93
	390.8	100

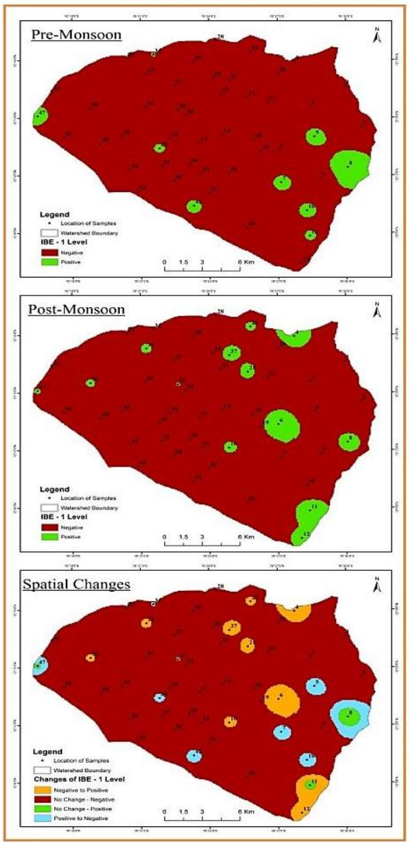
Fig 4 Spatial Distribution and Changes of SAR

Table 2: post Monsoon

Post - Monsoon											
Location	**EC**	**pH**	**Ca**	**Mg**	**Na+K**	**HCO_3**	**CO_3**	**Cl**	**NO_3**	**SO_4**	**TDS**
1	1240	7.65	56	56	113	551	0	56	36	58	791
2	3180	6.76	242	81	320	967	0	366	236	131	2016
3	1921	7.55	99	34	262	796	0	133	66	65	1225
4	1536	7.8	128	85	46	441	0	195	39	95	933
5	2101	7.12	120	123	138	772	0	182	110	68	1273
6	2134	7.15	224	98	50	490	0	330	78	134	1190
7	1405	7.55	108	50	106	453	0	158	69	45	799
8	1854	7.08	120	93	128	429	0	224	230	85	1125
9	2877	6.98	70	62	454	624	0	546	142	26	1822
10	2448	7.63	74	111	267	722	0	252	210	103	1515
11	2026	7.55	72	163	78	674	0	268	90	0	1108
12	1737	7.37	96	120	73	711	0	133	51	55	958
13	1320	6.88	101	47	100	603	0	70	12	56	718
14	909	7.09	82	25	67	441	0	39	19	23	506
15	1053	6.91	123	8	87	470	0	50	37	40	610
16	3019	6.18	432	558	1249	1012	0	3580	135	100	1769
17	515	7.5	45	20	30	235	0	28	7	20	278
18	1971	6.26	165	63	163	495	0	207	216	110	1201
19	1913	6.5	169	67	133	505	0	199	218	84	1153
20	2121	7.99	122	121	120	833	0	154	129	55	1217
21	2227	6.53	192	108	89	534	0	227	315	98	1396
22	1150	6.76	74	63	62	573	0	36	30	30	612
23	1009	7.71	42	51	10	366	0	28	4	0	308
24	547	7.42	45	28	22	269	0	28	12	5	285
25	1152	6.64	110	48	50	517	0	70	20	37	625
26	1151	6.9	88	60	51	436	0	81	60	55	643
27	1257	7.41	82	62	78	549	0	50	61	56	644
28	1401	6.38	101	70	75	547	0	106	60	53	768
29	1106	7.27	101	44	56	505	0	67	24	25	600
30	2472	6.53	241	86	232	709	0	272	270	270	1532
31	1194	6.94	64	63	83	586	0	45	23	35	636
32	1740	7.28	66	98	69	621	0	76	71	46	896
33	1800	7.3	127	46	70	506	0	123	66	22	516
34	1200	6.88	86	66	34	486	0	39	72	40	686
35	1300	7.33	70	61	32	426	0	42	42	56	864
36	790	7.81	65	25	58	386	0	34	8	22	606
37	1009	7.71	42	51	10	366	0	28	4	0	308
38	1518	7.31	48	67	101	560	0	56	56	34	566
39	1400	7.49	76	40	51	425	0	36	12	31	556
40	1084	8.16	43	29	66	386	0	22	3	22	536
41	2112	7.62	44	94	103	798	0	20	5	38	1126
42	850	7.89	86	62	34	526	0	34	26	28	520
43	1503	7.48	113	73	44	620	0	50	65	52	892
44	1010	7.6	76	28	54	392	0	28	34	28	564
45	700	7.48	62	32	32	364	0	22	11	19	396
46	1853	7.35	47	107	83	620	0	73	80	65	1050
47	1297	7.58	84	128	59	684	0	95	56	82	602
48	578	7.99	64	50	58	485	0	25	23	44	396
49	542	7.7	62	38	109	586	0	25	22	18	384
50	1780	7.66	69	102	81	576	0	143	85	28	808

Table: 3 Classification of Groundwater based on HYCH Program for Post-Monsoon in Hebbahalla watershed

Location	Indices of Base Exchange		Schoeller's Water Type	RSC	SAR	Saturation Indices		Honda's	Groundwater	Water Type	Sub Type	Sig. Enmt	Gibbs plot
	IBE_1	IBE_2				Ca	Phd-Phe	Class	Facies		(Based on ALK)		
1	-2.11	-0.31	IV	1.63	2.55	-0.73	0.85	B1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
2	-0.35	-0.16	III	-2.89	4.55	-1.28	0.84	A1C5S2	Ca Mixed	B	ALK-HIGH	(+)	EVAPORATION
3	-2.04	-0.49	III	5.31	5.79	0.32	1.16	B2C3S2	Na+K HCO3	F	ALK-HIGH	(+)	EVAPORATION
4	0.64	0.36	III	-6.15	0.77	0.05	1.26	A2C5S1	Mg Mixed	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
5	-0.17	-0.05	III	-3.46	2.11	0.42	0.8	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
6	0.77	0.59	III	-11.2	0.7	0.51	0.9	A2C3S1	Ca Mixed	B	ALK-HIGH	(.)	ROCK INTERACTION
7	-0.03	-0.02	III	-2.08	2.11	-0.09	0.95	A1C3S1	Ca HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
8	0.12	0.06	III	-6.61	2.13	-0.04	0.5	A2C3S1	Mg Mixed	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
9	-0.28	-0.33	IV	1.63	9.52	-11.2	0.33	B3C5S3	NA+K CI	B	ALK-HIGH	(+)	ROCK INTERACTION
10	-0.63	-0.26	IV	-0.99	4.58	0	1.07	A1C4S2	Mg Mixed	F	ALK-HIGH	(+)	EVAPORATION
11	0.55	0.33	I	-5.96	1.16	-0.1	0.95	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
12	0.15	0.04	III	-3.01	1.17	0.22	0.92	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
13	-1.2	-0.21	III	0.97	2.06	-7.77	0.38	B1C3S1	Ca HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
14	-1.65	-0.23	III	1.08	1.66	-0.48	0.36	B1C3S1	Ca HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
15	-1.68	-0.26	III	0.91	2.05	-8.23	0.38	B1C3S1	Ca HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
16	0.46	2.24	IV	-50.9	9.35	-0.22	0.53	A2C5S3	Mg CL	B	ALK-VERY-HIGH	(-)	ROCK INTERACTION
17	-0.65	-0.12	III	-0.04	0.94	-4.05	0.24	A1C2S1	Ca HCO3	G	ALK-MODERATE	(+)	ROCK INTERACTION
18	-0.21	-0.09	III	-5.31	2.74	-5.54	-0.12	A2C3S1	Ca Mixed	F	ALK-HIGH	(+)	ROCK INTERACTION
19	-0.03	-0.01	III	-5.67	2.19	-5.26	0.14	A1C3S1	Ca Mixed	F	ALK-HIGH	(+)	ROCK INTERACTION
20	-0.2	-0.05	III	-2.39	1.84	0.47	1.71	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
21	0.4	0.16	III	-9.72	1.27	-4.21	0.25	A1C3S1	Ca Mixed	F	ALK-HIGH	(+)	EVAPORATION
22	-1.65	-0.16	III	-1.65	-0.16	-11.6	0.1	B1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
23	0.02	0.01	III	-1	1.41	-11.4	-0.13	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
24	-0.21	-0.04	III	-0.14	0.63	-3.41	0.22	A1C2S1	Mg HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
25	-0.1	-0.02	III	-0.97	1	-8.39	0.11	A1C3S1	Ca HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
26	0.03	0.01	III	-2.18	1.03	-12.9	0.2	A1C3S1	Mg HCO3	F	ALK-MOD-IGH	(+)	ROCK INTERACTION
27	-1.4	-0.18	III	-0.2	1.58	-0.19	0.78	A1C3S1	Mg HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
28	-0.09	-0.02	III	-1.84	1.4	-8.66	-0.17	A1C3S1	Mg HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
29	-0.29	-0.06	III	-0.38	1.17	-0.05	0.69	A1C3S1	Ca HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
30	-0.31	-0.11	III	-7.48	3.26	-2.12	0.48	A2C5S2	Ca Mixed	F	ALK-HIGH	(+)	EVAPORATION
31	-1.84	-0.22	III	1.23	1.76	-13.2	0.23	B1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
32	-0.4	-0.07	III	-1.18	1.26	-0.3	0.61	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
33	0.12	0.04	III	-1.83	1.35	0.17	0.82	A1C3S1	Ca HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
34	-0.34	-0.04	III	-1.76	0.67	-11.8	0.21	A1C3S1	Mg HCO3	F	ALK-MOD-HIGH	(+)	EVAPORATION
35	-0.17	-0.02	III	-1.53	0.67	-0.79	0.52	A1C3S1	Mg HCO3	F	ALK-MOD-HIGH	(+)	EVAPORATION
36	-1.63	-0.23	III	1.03	1.55	-1.13	0.92	B1C3S1	Ca HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
37	0.45	0.06	I	-0.29	0.25	-2.47	0.61	A1C2S1	Mg HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
38	-1.78	-0.26	III	1.27	2.21	-0.99	0.45	B1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
39	-1.18	-0.15	III	-0.12	1.18	-0.65	0.71	B1C3S1	Ca HCO3	F	ALK-MOD-HIGH	(+)	ROCK INTERACTION
40	-3.62	-0.33	IV	1.79	1.91	0.68	1.09	B1C2S1	Mg HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
41	-6.94	-0.28	II	3.15	2.01	-0.52	0.88	B1C3S1	Mg HCO3	G	ALK-MOD-HIGH	(+)	EVAPORATION
42	-0.54	-0.05	III	-0.77	0.68	-0.18	1.26	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
43	-0.36	-0.04	III	-1.49	0.79	0.24	1.04	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
44	-1.97	-0.21	III	0.33	1.34	-0.79	0.79	B1C3S1	Ca HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
45	-1.24	-0.12	III	0.24	0.82	-1.37	0.55	B1C2S1	Ca HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
46	-0.75	-0.12	III	-0.99	1.53	-0.83	0.53	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	EVAPORATION
47	0.04	0.01	III	-3.51	0.95	0.07	1.05	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION
48	-2.58	-0.2	II	0.64	1.32	-0.72	1.19	B1C3S1	Mg HCO3	G	ALK-MOD-HIGH	(+)	ROCK INTERACTION
49	-5.72	-0.39	IV	3.38	2.69	-0.47	0.97	B1C3S1	Mg HCO3	G	ALK-HIGH	(+)	ROCK INTERACTION
50	0.13	0.45	III	-2.4	1.45	-0.34	0.97	A1C3S1	Mg HCO3	F	ALK-HIGH	(+)	ROCK INTERACTION

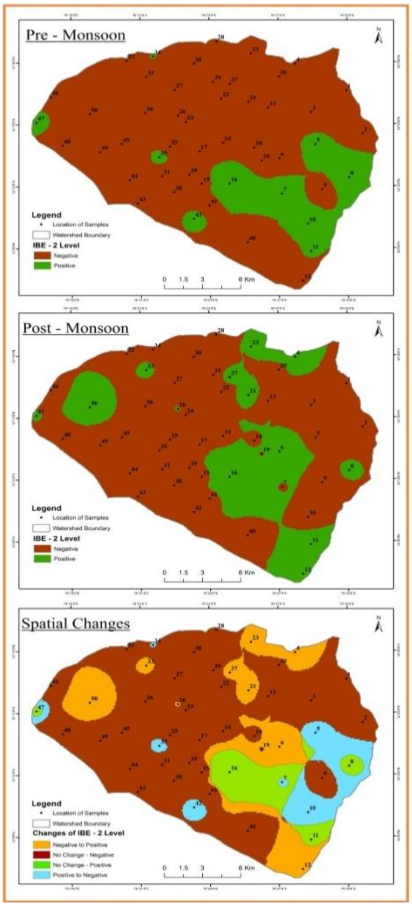


Distribution of IBE-1 (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
Positive	9	17.7	4.53
Negative	41	373.1	95.5
Source: Calculated by Researcher		390.8	100

Distribution of IBE-1 (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
Positive	13	25.19	6.45
Negative	37	365.61	93.55
Source: Calculated by Researcher		390.8	100

IBE-1 Changes from Pre to Post Monsoon		
Changes	Area	Area in %
No Change - Positive	3.15	0.81
No Change - Negative	351.06	89.83
Positive to Negative	14.55	3.72
Negative to Positive	22.04	5.64
Source: Calculated by Researcher	390.8	100

Fig. 5 Spatial Distribution and Changes of IBE_1 in Hebbahalla watershed

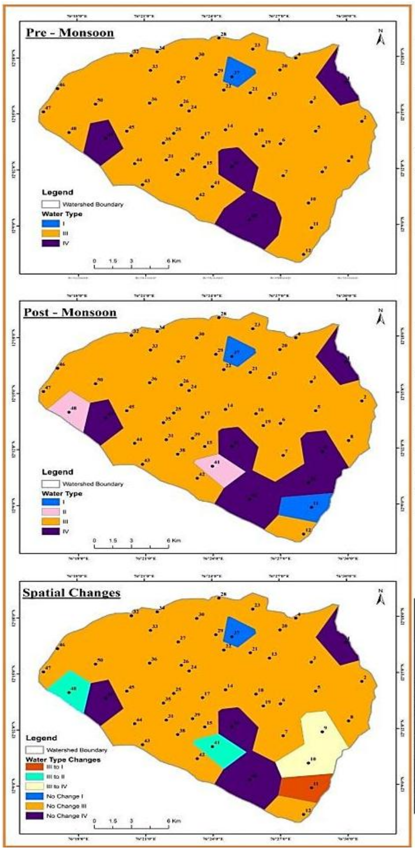


Distribution of IBE-2 (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
Positive	10	70.7	18.1
Negative	40	320.1	81.9
Source: Calculated by Researcher		390.8	100

Distribution of IBE-2 (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
Positive	13	106.97	27.37
Negative	37	283.83	72.63
Source: Calculated by Researcher		390.8	100

IBE-2 Changes from Pre to Post Monsoon		
Changes	Area	Area in %
No Chnage - Negative	246.84	63.16
Negative to Positive	73.26	18.75
Positive to Negative	36.99	9.47
No Change - Positive	33.71	8.63
Source: Calculated by Researcher	390.8	100

Fig.6 Spatial Distribution and Changes of IBE_ 2



Distribution of SCHOELLER'S WATER TYPE (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
I	1	4.91	1.26
II	0	0	0
III	45	338.34	86.6
IV	4	47.56	12.2
Source: Calculated by Researcher		390.8	100

Distribution of SCHOELLER'S WATER TYPE (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
I	2	13.9	3.56
II	2	14.66	3.75
III	40	292.31	74.8
IV	6	69.93	17.89
Source: Calculated by Researcher		390.8	100

SCHOELLER'S WATER TYPE Changes from Pre to Post Monsoon		
Changes	Area	Area in %
No Change I	4.91	1.26
No Change III	292.31	74.8
No Change IV	47.56	12.17
III to I	8.99	2.3
III to II	14.66	3.75
III to IV	22.37	5.72
Source: Calculated by Researcher	390.8	100

Fig.7 Spatial Distribution and Changes of Scholler's water type

The distribution of Electrical Conductance during the Pre-Monsoon 7.16 km^2 area comes under 700-1000 EC range which has a Permissible water quality, while as 383.64 km^2 have the EC range of more than 1000 which has a doubtful water quality. During the Post-Monsoon, 5.07 km^2 comes under 500-700 EC range which has a Good water quality, 39.11 km^2 have the EC range of 700-1000 that is having Permissible water quality and 346.62 km^2 comes under the EC range of more than 1000 which has a doutful water quality(**Fig 3).**

The changes between pre and post-monsoon shows that the EC range of > 1000 to 500 – 700 has a changed to 4.61km^2 area, EC range of > 1000 to 700-1000 shows the change of 36.55 km^2, 700-1000 to > 1000 of EC range shows the change of 4.14 km2, 700-1000 to 500-700 of EC range shows the change of 0.46 km^2, while as EC range of >1000 and 700-1000 shows the no change.

4.3 Sodium Adsorption Ratio

The result of SAR study can find out the suitability of water for agriculture irrigation use. The spatial distribution of SAR result shows that entire study area 390.80 km^2 is in excellent class during the pre-monsoon, while 34.90 km^2 during the post-monsoon have been changed into good class. The spatial change (**Fig 4.)** shows the areas where the changes occurred, the result clearly shows that, SAR values in the groundwater have been decreased after the monsoon.

4.4 Spatial Distribution and Changes of Indices of Base Exchange

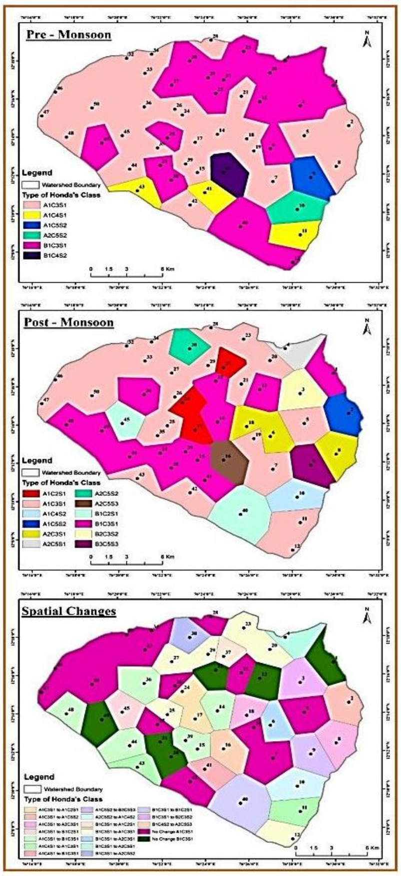
In the present study IBE -1 shows during the pre-monsoon 17.70 km^2 area were had positive values while 373.10 km^{2}area were had negative values. These values had been changed during post-monsoon as 25.19 km^2 in positive and 365.61 km^2 in negative **(Fig 5),** which clearly shows the area of negative values have been decreased and positive have been increased slightly after the monsoon (**Table 2 &3).**

The result of IBE -2 shows that, 70.70 km^2 had positive values and 320.10 km^2 had negative values during the pre-monsoon season and this values have been changed as 106.97 km^2 in positive and 283.83 km^2**(Fig6)** in negative during the post-monsoon season, which also represents the area of negative increased while positive decreased after the monsoon. The comparison of IBE- I and IBE-II spatial and temporal changes clearly depicts that, the spatial changes were high in the values of IBE-II than IBE-I.

4.5 Scholler's Water Type

The study of Scholler's water type shows that, 4.91 km^2 area were covered by type I, 338.34 km^2 were covered by type III and 47.56 km^2 were covered by type IV while no area have covered by type II during pre-monsoon season **(Fig 7 and Table 2 &3).**

The area were covered by type I during the post-monsoon were 13.90 km^2, type II were 14.66 km^2,

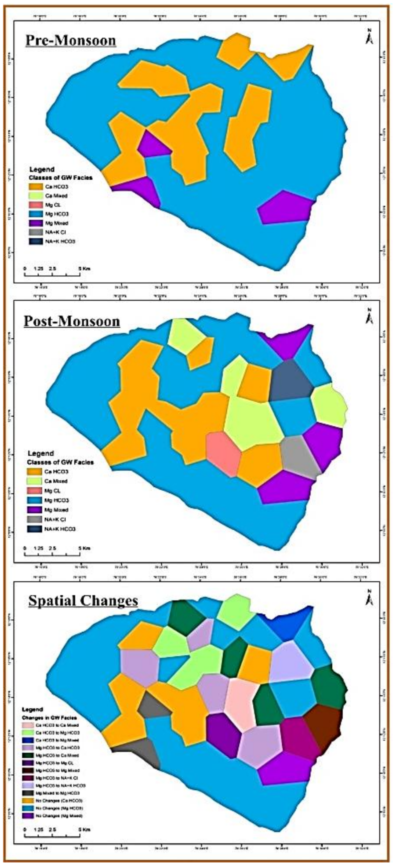


Distribution of HANDA'S CLASSIFICATION (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
A1C3S1	26	194.5	49.8
A1C4S1	3	22.22	5.69
A1C5S2	1	10.66	2.73
A2C5S2	1	11.71	3
B1C3S1	18	141.75	36.3
B1C4S2	1	9.95	2.55
Source: Calculated by Researcher		390.8	100

Distribution of HANDA'S CLASSIFICATION (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
A1C2S1	3	16.08	4.11
A1C3S1	22	158.59	40.58
A1C4S2	1	11.71	3
A1C5S2	1	10.06	2.57
A2C3S1	3	25.53	6.53
A2C5S1	1	7.58	1.94
A2C5S2	1	7.73	1.98
A2C5S3	1	9.95	2.55
B1C2S1	2	28	7.16
B1C3S1	13	93.15	23.84
B2C3S2	1	11.76	3.01
B3C5S3	1	10.66	2.73
Source: Calculated by Researcher		390.8	100

HANDA'S CLASSIFICATION Changes from Pre to Post Monsoon		
Changes	Area	Area in %
A1C3S1 to A1C2S1	11.17	2.86
A1C3S1 to A1C5S2	10.06	2.57
A1C3S1 to A2C3S1	17.59	4.5
A1C3S1 to B1C2S1	8.2	2.1
A1C3S1 to B1C3S1	43.38	11.1
A1C4S1 to A1C3S1	15.05	3.85
A1C4S1 to B1C3S1	7.18	1.84
A1C5S2 to B3C5S3	10.66	2.73
A2C5S2 to A1C4S2	11.71	3
B1C3S1 to A1C2S1	4.91	1.26
B1C3S1 to A1C3S1	39.44	10.09
B1C3S1 to A2C3S1	7.94	2.03
B1C3S1 to A2C5S1	7.58	1.94
B1C3S1 to A2C5S2	7.73	1.98
B1C3S1 to B1C2S1	19.8	5.07
B1C3S1 to B2C3S2	11.76	3.01
B1C4S2 to A2C5S3	9.95	2.55
No Change A1C3S1	104.11	26.64
No Change B1C3S1	42.6	10.9
Source: Calculated by Researcher	390.8	100

Fig 8 Spatial Distribution and Changes of Handa's Class

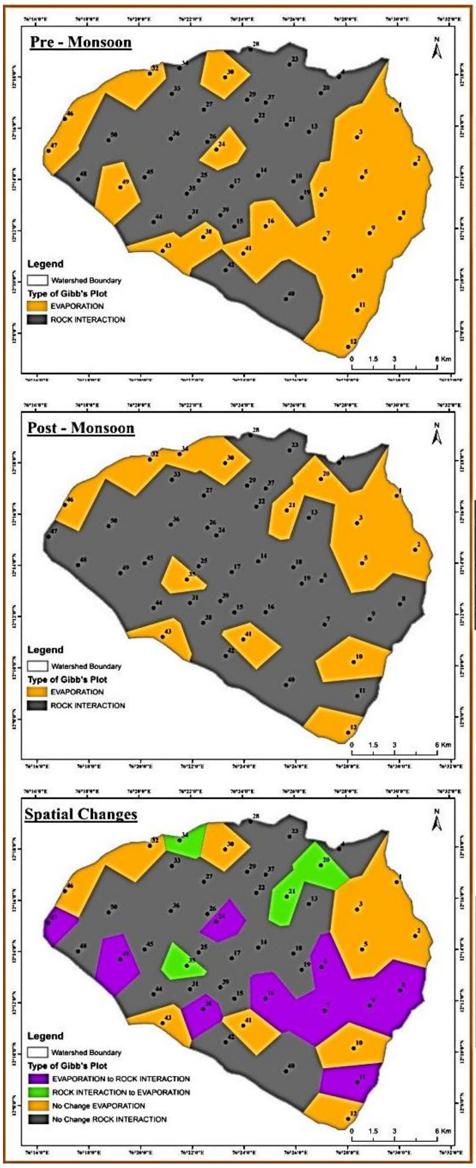


Facies Pre-Monsoon		
Classes	Area (Sq KM)	Area (%)
Ca HCO3	97.81	25.03
Mg HCO3	270.34	69.2
Mg Mixed	22.54	5.77
	390.8	100
Source: Calculated by Researcher		

Facies Post-Monsoon		
Classes	Area (Sq KM)	Area (%)
Ca HCO3	88.22	22.58
Ca Mixed	43.77	11.2
Mg CL	9.95	2.55
Mg HCO3	196.25	50.23
Mg Mixed	30.07	7.7
NA+K CI	10.67	2.73
NA+K HCO3	11.76	3.01
	390.8	100
Source: Calculated by Researcher		

Facies Changes from Pre to Post Monsoon		
Changes	area	Area (%)
No Changes (Ca HCO3)	51.99	13.31
Ca HCO3 to Ca Mixed	11.86	3.04
Ca HCO3 to Mg HCO3	26.37	6.75
Ca HCO3 to Mg Mixed	7.59	1.94
Mg HCO3 to Ca HCO3	36.23	9.27
Mg HCO3 to Ca Mixed	31.91	8.17
Mg HCO3 to Mg CL	9.95	2.55
No Changes (Mg HCO3)	159.06	40.71
Mg HCO3 to Mg Mixed	10.76	2.75
Mg HCO3 to NA+K CI	10.67	2.73
Mg HCO3 to NA+K HCO3	11.76	3.01
Mg Mixed to Mg HCO3	10.82	2.77
No Changes (Mg Mixed)	11.72	3
Source: Calculated by Researcher	390.8	100

Fig.9 Spatial Distribution and Changes



Distribution of GIBB'S PLOT (Pre-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
EVAPORATION	21	182.48	46.7
ROCK INTERACTION	29	208.32	53.3
Source: Calculated by Researcher	50	390.8	100

Distribution of GIBB'S PLOT (Post-Monsoon)			
Class Name	Number of Sample	Area Sq Km	Area in %
EVAPORATION	15	119.46	30.57
ROCK INTERACTION	35	271.34	69.43
Source: Calculated by Researcher	50	390.8	100

GIBB'S PLOT Changes from Pre to Post Monsoon		
Changes	Area	Area in %
EVAPORATION to ROCK INTERACTION	86.04	22.02
ROCK INTERACTION to EVAPORATION	23.01	5.89
No Change EVAPORATION	96.45	24.68
No Change ROCK INTERACTION	185.3	47.42
Source: Calculated by Researcher	390.8	100

Fig.10 Spatial Distribution and Changes of

292.31 km^2 were type III and 69.93 km^2 were covered by type IV, which clearly represents the changes of water type between pre and post-monsoon season.

The changes of Scholler's water type between pre and post-monsoon season shows the influence of the monsoon rainfall in the groundwater.

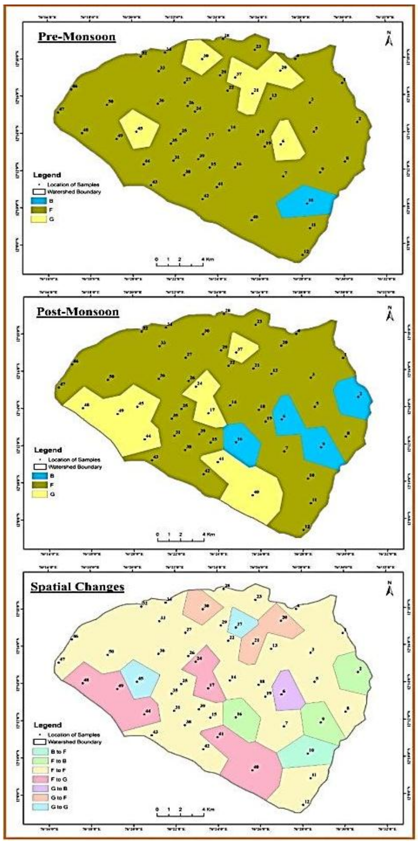
4.6. Handa's Classification

The study conducted to find out the classification water quality based on the Handa shows that, $A_1C_3S_1$ (194.50 km^2), $A_1C_4S_1$ (22.22 km^2), $A_1C_5S_2$ (10.66 km^2), $A_2C_5S_2$ (11.71 km^2), $B_1C_3S_1$ (141.75 km^2) and $B_1C_4S_2$ (9.95 km^2) were covered during the pre-monsoon (Fig 8). The number of classes based on the Handa's classification have been increased as $A_1C_2S_1$ (16.08 km^2), $A_1C_3S_1$ (158.59 km^2), $A_1C_4S_2$ (11.71 km^2), $A_1C_5S_2$ (10.06 km2), $A_2C_3S_1$ (25.53 km^2), $A_2C_5S_1$ (7.58 km^2), $A_2C_5S_2$ (17.73 km^2), $A_2C_5S_3$ (9.95 km^2), $B_1C_2S_1$ (28.00 km^2), $B_1C_3S_1$ (93.15 km^2), $B_2C_3S_2$ (11.76 km^2) and $B_3C_5S_3$ (10.66 km^2) during the post-monsoon which clearly states the influence of monsoon rainfall in the changes of groundwater in the study area.

4.7 Groundwater Facies

The study conducted to find out the groundwater facies in the study area shows that, three different classes were covered the study area during the pre-monsoon, such as, Ca HCO_3 (97.81 km^2), Mg HCO_3 (270.34 km^2) and Mg Mixed (22.54 km^2). This three classes have been increased during the post-monsoon as Ca HCO_3 (88.22 km^2), Ca Mixed (43.77 km^2), Mg CL (9.95 km^2), Mg HCO3 (196.25 km^2), Mg Mixed (30.07 km^2), Na+K CI (10.67 km^2) and Na+K HCO_3 (11.76 km^2).

The analysis of changes between pre and post-monsoon shows clearly the huge changes of facies between two seasons the detailed changes values are given in (Fig 10 and Table 2 &3).

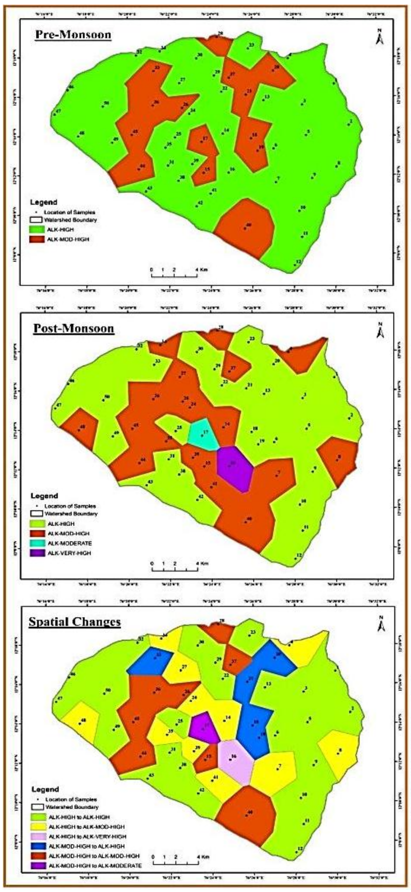


Water Type (Pre-Monsoon)		
Class Name	Area Sq Km	Area in %
B	11.71	3.00
F	336.42	86.09
G	42.67	10.92
	390.80	100.00
Source: Calculated by Researcher		

Water Type (Post-Monsoon)		
Class Name	Area Sq Km	Area in %
B	38.61	9.88
F	274.74	70.30
G	77.45	19.82
	390.80	100.00
Source: Calculated by Researcher		

Water Type Changes from Pre to Post Monsoon		
Changes	Area	Area in %
B to F	11.71	3.00
F to B	30.67	7.85
F to F	241.40	61.77
F to G	64.34	16.46
G to B	7.94	2.03
G to F	21.63	5.53
G to G	13.11	3.35
	390.80	100.00
Source: Calculated by Researcher		

Fig.11 Spatial Distribution and Changes of water types



Sub Watertype ALK (Pre-Monsoon)		
Class Name	Area Sq Km	Area in %
ALK-HIGH	287.03	73.45
ALK-MOD-HIGH	103.77	26.55
	390.80	100.00
Source: Calculated by Researcher		

Sub Watertype ALK (Post-Monsoon)		
Class Name	Area Sq Km	Area in %
ALK-HIGH	230.70	59.03
ALK-MOD-HIGH	144.47	36.97
ALK-MODERATE	5.68	1.45
ALK-VERY-HIGH	9.95	2.55
	390.80	100.00
Source: Calculated by Researcher		

Sub Watertype ALK Changes from Pre to Post Monsoon		
Changes	Area	Area in %
ALK-HIGH to ALK-HIGH	197.76	50.60
ALK-HIGH to ALK-MOD-HIGH	79.32	20.30
ALK-HIGH to ALK-VERY-HIGH	9.95	2.55
ALK-MOD-HIGH to ALK-HIGH	32.93	8.43
ALK-MOD-HIGH to ALK-MOD-HIGH	65.15	16.67
ALK-MOD-HIGH to ALK-MODERATE	5.68	1.45
Source: Calculated by Researcher	390.80	100.00

Fig.12 Spatial Distribution and Changes of Sub water types

4.8 Gibb's Plot

The study of Gibb's plot shows that, the study area have been covered by two different classes during the pre-monsoon such as, evaporation (182.48 km^2) and rock interaction (208.32 km^2). The area covered by these two classes have been changed after the monsoon as evaporation (119.46 km^2) and rock interaction (271.34 km^2) which clearly states the decrease in evaporation and increase in rock interaction from pre to post-monsoon. The detailed values are given in (**Fig 10 and Table 2 &3).**

4.9 Water Type

The study conducted to analysis the water type in the study area depicts three types of water type are present in the groundwater in both the seasons, such as, B, F and G. The area covered by type B was 11.71 km^2 during the pre-monsoon and it has been increased into 38.61 km2 during the post-monsoon, and the area covered by F was 336.42 km^2 during the pre-monsoon and it has been decreased into 274.74 km^2 during the post-monsoon. The area of type G was 42.67 km^2 during pre-monsoon and it has been increased into 77.45 km^2 during the post-monsoon. The result clearly shows the increased area of B and G from pre to post-monsoon while type F decreased. The detailed data have presented in (**Fig 11).**

4.10. Subwater type ALK

The analysis of water type ALK shows that, there were two kinds of classes available during the pre-monsoon namely, ALK-HIGH and ALK-MOD-HIGH which covered 287.03 km^2 and 103.77 km^2 respectively. This pre-monsoon classes and areas have been changed into four classes during the post-monsoon as, ALK-HGH, ALK-MOD-HIGH, ALK-MODERATE and ALK-VERY-HIGH, which areas were, covered 230.70 km^2, 144.47 km^2, 5.68 km^2 and 9.95 km^2 respectively. The result shows the influence of monsoon rainfall for the changes of water quality in the study area **(Fig 12)**

Conclusion

The chemical aspects of the groundwater has been determined in Hebbahall watershed, the results obtained shows the alkaline nature of water. The TDS present in water shows that the samples are suitable for drinking and irrigation purposes after taking some remedial measures. It is advisable to avoid soils having excessive alkalinity and low calcium and magnesium contents while digging wells in search of potable waters. The determination of alkalinity and hardness of existing waters can be expected to be helpful which reflects the geochemical character of groundwater and nature of the rocks in which it occurs**.**

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