Research Paper

Volume : 3 | Issue : 11 | November 2014 • ISSN No 2277 - 8179

Geostatistical Analysis of Groundwater in and Around Kadiri, Anantapur District, Andhra Pradesh, India

Geology

KEYWORDS : Kadiri,Groundwater quality, Factor analysis, principal component analysis, cluster analysis, correlation coefficient and validation techniques.

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ABSTRACT

Geostatistical analysis of groundwater were carried out in and around Kadiri,Anantapur district of Andhra Pradesh. In the present study 41 hydro chemical data of groundwater samples for both the seasons (pre monsoon and post monsoon) were collected from different locations of the study area. Eight variables Ca, Mg, Na + K, SiO2, HCO3, SO4, Cl and EC were used in the study. Statistical analysis was carried out by using software STATISTICA. Further, multivariate statistical methods were used. Statistical methods can be classified as independent method and dependent method. From the dependent method, it is noted that a variable or set of variables was taken as dependent one and the remaining variables as independent/s (Regression analysis).By this method it is possible to predict the groundwater characters of an area. But in the independent method all variables were analysed as single sets(Cluster analysis, Principal components and Factor methods)Using this technique the deterministic model can be obtained, which evaluates the groundwater quality , and also analyses the underlying parameters of relationships for a group of variables.

Introduction

The study area is a part of Kadiri schist belt, which is in Anantapur district, Andhra Pradesh. The study area lies between North latitude 14^0 00"and 14^0 10' and East longitude 78^0 05' and 78^0 15' in the survey of india toposheet no 57J/4 The total catchment area is about332sq.km.(Fig.1).

The area consists of a number of isolated clusters of hillocks amidstan otherwise gently undulating plateau.The schist belt is a plain area dotted with occasional hills.On either side of the schist belt granitic rocks form high hills.The elevation in the area ranges beween 265 and 1500ft.The soil is coarse- grained over granitic terrain and fine to medium grained over over schist belt rocks.Sandy soil occurs along the river course.

In the study areadendritic to sub-dendritic pattern typical ofany crystalline rocks can be recognized.NorthwesternflowingMadduleru river,which if the main tributary ofChitravathi,drains Kadiri area.The drainage pattern of the area is mainly structurally controlled.

The area experiences extreme climatic conditions as it is situated in subtropical zone , with maximum temperature ranging between38^{0}Cand45^0 C during summer and minimum temperature between 14^0 C and 30^{0}C during winter. The area does not get the full benefits either from south west monsoon or north east monsoon due to located away from the coast. Thus the area is deprived of both the monsoons and subjected to recurrent droughts. Annual rainfall of the area is 666 mm. On an average Kadiri has 40 rainy days (days having more than 2.5 mm of rainfall) in a year

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The rock formations of the study area are mainly occupied by Kadiri schist belt. It is a linear green stone belt situated in the eastern part of the Dharwar craton and south western part of the Cuddapah basin. The schist belt consists of mainly acid volcanics with minor amount of basic volcanics. Acid volcanics represents rhyolite, rhyodacite, quartz porphyry, quartz felspar porphyry, muscovite sericite after schist , quartz sericite schist and Basic volcanics consists of meta-basalt and amphibolites. The schist belt has on either side by sin to post tectonic granitoids which constitute mostly granodiorite-tonalites units in the east and granite suit in the west. On the eastern most side of the study area granites follow granodiorite-tonalite suite. At places, pink granite in the granodiorite-tonalite units on the eastern margin shows a clear cut intrusive contact with the schist belt units.The central portion of the study area constitutes the schist belt, which runs roughly in the NNW-SSE direction (Fig .2)

HYDROCHEMISTRY.

Water is the essential for survival of life. However ,The problems os assessment of water resource and utilization are not fully evaluated due to lack of awareness of the importance of a planned management for conjunctive use of groundwater. Though,annual rain is normal in general in large part of the peninsular india.,considerable amount of surface water is lost resulting in excessive dependence on groundwater for irrigation besides drinking.

Quality of water is as essential as its quantity for survival of flora and fauna.Owing to growing population, urbanization and industrialization it has become imperative for periodic evaluation of groundwater quality for its suitability in relation to drinking and agriculture.Groundwater quality is mainly a function of the rock types and the residence time with which it is associated besides the role played by altitude,soils, clmate and weathered mantle.Hence the difference in the relative proportion of the principal ions in groundwater in different depths can be attributed variation in geology.It is not possible to prevent dissolution of undesirable constituents once the wate enters the groundsurface.(Pojasek,1977andJohnson,1979)The study of quality is to rate waters for drinking and agriculture purposes.

SAMPLING AND METHODS OF ANALYSIS.

The procedures followed for sampling and preservation are those given by international standard methods. Water samples from different formations were collected both in pre-and post monsoon seasons in norder to know the quality variation.

The constituents and properties of 41 water samples of both the seasons (premonsoon and postmonsoon)were analysed . They include silica, calcium, magnesium, sodium, potassium, carbonate, bicarbonate, Sulphate, chloride, dissolved solids, alkalinity, hardness, noncarbonated hardness, specific conductance, hydrogen-ion-concentration(pH), sodium adsorption ratio, and percent sodium were determined in the field by using a field geochemical kit, consisting of a battery-operated Ph meter and conductivity meter, and portable equipment to carryout potentiometric titrations. Water samples both from surface water bodies and wells were collected at a depth of 1 m below the top of the water level. When water column was less than 2 m in depth,the water sample was collected approximately at the midpoint of the water column. Standard methods for collection, preservation, analysis and interpretation of water samples were followed (RainwaterandThatcher,1960;Hem, 1970; and AWWA, 1971). A Systronic digital spectrophotometer was used for the estimation of silica by the molybdate blue method and fluoride by the Zirconium-Eriochrome cyanine R method. Nitrate was estimated by the brucine method, where the intensity of the yellow color produced by the reaction between brucine and nitrate in an acid medium was determined by using a spectrophotometer (Jenkins and Medsker, 1964). Sodium and potassium were estimated by using a Systronics digital flame photometer. Hardness as$CaCO_3$ and calcium were estimated by the complexiometric titration methods and chloride by the titration method of Mohr. Magnesium was calculated from hardness and calcium. Sulphate was estimated by the turbidimetric method. Dissolved solids were estimated both by the calculation and residue on evaporation methods. The reliability of chemical analyses was established by noting the sum of cations as me/l to be nearly same as the sum of anions as me/l. Sodium adsorption ratio was calculated by dividend sodium in me/l by the square root of one half of the sum of calcium and magnesium in me/l. Residual sodium carbonate in me/l was taken as zero if the sum of the calcium and magnesium in me/l was equal to or more than the sum of carbonate and bicarbonate in me/l, otherwise, it was taken as twice the difference between the two sums.

Geostatistics refers to a set of statistical procedure for describing the correlation of spatially distributed randam variables .Statistical technique offers several advantages over other spatial estimation techniques, the primary advantage being that it incorporates the spatial characterstics of that data,and helps in obtaining more precise estimates. Geostatistical techniques were initially applied for estimating the the ore reserves and subsequently extended to many other spatialvariablesincludingthe mapping and modeling of groundwater (Delhome,1978;; Istok et al.,1993,DasGuptaet al,1998 ,Gupta 2004 ,Dash et.al,2010.,Fabrizio Felleti et.al.2006.,Hannes Thiergartner,2006)

The level of chemical concentration in water is very important in evaluating the quality of water. The hydrochemical modelling plays a vital role in understanding the interrelationship between the constituents of the water

1.3MATERIALS&METHODS

1.3.1 FACTOR ANALYSIS AND CLUSTER ANALYSIS

Factor analysis is a tool in processing large data set in which the objective is to discuss the influence of causal factors that are responsible for variation in the data. The water samples were processed for R- mode factor analysis. The detailed explanation of the methodology for R-mode factor analysis modeled after Harman (1970), Cooley and Lohnes (1971) and Davis (1986) , Drever (1988) indicated that R-mode factor analysis was applied to geochemical problems where no relationship between variables could be presumed. According to Lawrence and Upchurch(1982) the factor analysis is an aid in sorting out chemical variables related to hydrological process beyond strict litho logical controls. They used R-mode factor analysis in identifying those variables that were related to specific chemical process. This technique also delineates the areas influenced by each chemical process when the factor scores are mapped.

Basic statistics of hydro chemical data of 41 ground water samples for both the seasons (Pre monsoon and post monsoon) are given in the table 1 a and b

Eight variables Ca, Mg, Na + K, SiO_2, HCO_3, SO_4, Cl and EC were used in the study. The analysis was carried out using statistical software STATISTICA and the results of the analysis are presented as follows.

The literature on cluster analysis abounds after the publication of a book bySokal and Sneath (1963) entitled, “Principals of Numerical Taxonomy”. The number of application of cluster analysis in all scientific fields has doubled approximately once every three years from 1963-1990 (Aldenderber and Blassfield, n1990 and Padmanabha 2010). This rate of growth is much faster than that of even the most rapidly growing disciplines such as bio chemistry, bio technology and environmental science etc. There are two reasons for the rapid growth of the literature on cluster analysis: 1) The development of high speed computers, and 2) The fundamental importance of classification as a scientific procedure. Despite their popularity, clustering methods are not so extensively used in comparison to such multivariate statistical procedures as factor analysis, discriminate analysis and multidimensional scaling.

Cluster analysis reduces and organizes a large data set into groups with similar characteristics. It provides a forward straight logical and pair-by- pair comparison between various chemical constituents (variables). The results of cluster analysis are presented in an easily understandable two dimensional hierarchical diagram, on which the natural breaks between the groups become obvious. From this groups at any desired level of similaty/dissilarity can be picked up by any observer.(Robert and James, 1962). Ramachandran (1989), Ratha et al.(1992), and Lingeswara Rao (2003) adopted cluster analysis in their studies for different aspects.The results reported by Mahadev et al.(2003),Mrithunjaya et al. (2004)., Meenakumari et al.(2004)., Raut et al.(2006).,Mathew Thomas et al.(2006)., Patel and Desai(2006)., and Venkatasubramani et al(.2006) support the results of the present investigation

Hotelling (1933) Coined the term Principal Component Analysis. A Principal component analysis involves the extraction of un-correlated linear combination of the original variables in such a manner that each successively selected linear combination (termed Principal component) as a smaller variance. A set of observed independent variables are transformed into an orthogonal set of variants called principal components. The principal component accounts for as much as possible of the total variance of the observed variates. The second principal component accounts for as much as possible of residual variance not accounted by the first principal component. Likewise, each succeeding principal component accounts for as much as possible of the residual variance not accounted for, by all the previous principal components.

Many terms have been created to describe the important features concerned with the estimation of similarity. The terms ‘case’, ‘object’, ’pattern’ and OUT (Operational Taxonomic Unit) denote the ‘thing’ being classified, as where ‘variable’, ‘attribute ’,character’, and ‘feature’ denote those aspects of the ‘things’ used to assess their similarity. Another set of important terms of “Q-analysis”and “R-analysis”, refers to the relationships between variables. Cluster analysis, for instance, has been traditionally described as a "Q-mode" technique, as where factor analysis as "R-mode" method/

The potential user of cluster analysis should also note that data matrices are often organized in different ways. In the social sciences, the convention is to describe the data set as a matrix consisting of **N** cases (rows) measured on **P** variables (columns). In the biological sciences, this ordering is reversed, resulting in a P x N matrix of data. The term "raw data" is described as the original N x P matrix of variables before the calculation of similarity .. Computation of similarity measurement between all possible pairs of objects will result in an N x N symmetrical matrix. Everitt (1980) uses the term similarity coefficient to denote those measures which Sneath and Sokal (1973) sub divided these coefficients into four groups: 1) Correlation efficient, 2) Distance measures, 3) Association coefficients, and 4) probability similarity coefficients. Each of these methods have advantages and disadvantages. Although all four types are in use in the biological sciences, only correlation and distance coefficients are by extensively used.

Although many measures have been proposed, only two of them are widely used- the correlation coefficient and the distance co efficient. If raw data is standardized prior to computing the, the similarity coefficient, correlation coefficient and distance coefficient can be directly transformed into one another. The distance coefficient is not constrained within the range -1.0 to +1.0 as is the case in correlation coefficient. Hence, it may give more effective dendrograms if a few of the objects are very dissimilar from one another (Davis, 1973).

Technically, distance coefficients are best described as dissimilarity measures: most of the more popular coefficients demonstrate similarity by high values within their ranges, but distance measures are scaled the reverse. Two cases are identical, each one is described by variables with the same magnitudes. In this case, the distance between them is zero. Distance measures normally have no upper bounds, and are scale- dependant. Among the more popular representation of distance is Euclidean distance, and it is defined as

$$\mathbf{d_{ij}={}^{P}\Sigma_{k21}\,(X_{ik}-X_{jk})^2}$$

Where d_{ij} is the distance between cases i and j, and X_{ik} is the value of the K^{th} variable for the i^{th} case.

The correlation coefficient indicates greatest similarity at high positive values, while the distance coefficient indicates greatest similarity by the smallest distance therefore, correlation coefficients must be linked or inter connected at high values, and distance coefficients at low values

1.4 RESULTS AN DDISCUSSION

1.4.1 FACTOR ANALYSIS

1.4.2 Principal Component Analysis:

In this analysis, the similarity measures were found out as correlation between the variables. The correlation matrix was computed by the eigen values and per cent of trace or the amount of variance, which clearly described that all the variance was common or shared. Then the eigen vectors were calculated to bring out the variables loaded in components. The components scores for 41 samples were calculated for the two periods (i.e. pre-monsoon and post-monsoon).

Principal component loading matrixes for the two periods are given in table – 2. a & b.

After the construction of eigen vectors in the Principal Component analysis the factor analysis was iniated. In this analysis, only three factors were selected because 79% of the variance was explained by the first three components in Pre-Monsoon Period and 85% in Post-Monsoon period. Then the variables were loaded into three factors and factors scores were calculated (table-3) in the next step, the reproduced and residual correlation matrix was computed. After this varimax, rotation was added to maximize the difference between the variables. This process of adjustment or manipulation of the factor axes gives simple and meaningful factor solution. In the next stage, the commonalities were inserted in the diagonal of the correlation matrix and the extracted factors are based only on the common difference or variance as original variable shares with all other variables. Lastly, the rotated factor matrix and varimax factor scores were computed for direct interpretation. The details of rotated factor matrix are given in the table-4. a & b.

According to the Principal Component analysis, the leading chemical constituents are as listed below:

Component	Leading chemical Parameter (Pre-Monsoon Period)	Eigen Value	Per cent trace
I	Mg, Ca, Na, Cl and EC	3.47	43.45%
II	SO_4	1.51	18.89%
III	HCO_3	1.35	16.87%

Component	Leading chemical Parameter (Post-Monsoon Period)	Eigen Value	Per cent trace
I	Mg, Si, SO_4	2.48	35.50%
II	Ca, Cl, EC	2.47	30.96%
III	Na, HCO_3	1.56	19.47%

The first Principal Component is heavily loaded with 43.45% of trace in the Pre-monsoon period and the leading chemical constituents are Mg, Ca, Na, Cl, and EC. The variables Mg, Ca, and Cl are heavily and uniformly loaded with values of 0.814, 0.787 and 0.760 respectively. Negligible loading on SO_4 and HCO_3 indicates that their contribution is not important in determining the type /quality of waters. This component denotes that the waters are of with chloride factor or alkaline factor.

The component I of Post-Monsoon represented by SO_4, SiO_2, and Mg contributes 35.50% of the sample variance with values of 0.902, 0.929 and 0.811 respectively, but all the variables are negatively loaded. In this first factor, negative correlation among cations and anions except in Na indicates all other elements are mobile and sodium is only accumulating in the water.

The second Principal Component is positively and heavily loaded with SO_4 ion only with 18.89% of trace in the Pre-Monsoon. It shows little correlation with Mg and negative relation with Na indicating that this water is of Mg-SO_4 facies. In the case of Post-Monsoon period Ca and Cl ions dominated with 30.96% of variance Cl exhibits negative correlation with both Na and Mg indicating Ca-Cl facies to the water.

In the third component HCO_3 is the only variable loaded heavily and it accounts for only 16.87% of variance in the Pre-Monsoon period, whereas in the Post-Monsoon HCO_3 along with Na is heavily loaded variable with 19.47% of trace.

The dominance of HCO_3, SO_4 and Cl indicates the nature and age of waters (Chebotarev, 1955). He has demonstrated the major ion evolution sequence as travel along the flow path is with increasing age.

Travel along the flow path→

HCO_3→ HCO_3 + SO_4→ SO_4 + HCO_3→ SO_4+Cl→ Cl+SO_4→ Cl

Increasing age→

Increasing Residence Time→

This phenomenon has also been expressed by Freeze and Cherry (1979). Aravindan et al (2003) expressed that the ground water moves from shallow zones to active flushing, through the intermediate zone where the flow path is very sluggish and water is old.

As Schoeller (1965) described the dominance of Cl among anion and Na among cations indicates that the ground water is in the old stage. The heavily loaded chemical constituents in the rotated factor matrix for the two periods are as follows:

Factor	Leading chemical Parameters (Pre-Monsoon)	Eigen value	Percent Trace
I	Ca, Mg, Na, Cl,EC	3.48	43.45%
II	SO_4	1.51	18.89%
III	HCO_3	1.35	16.87%
Factor	Leading chemical Parameters (Past-Monsoon)	Eigen value	Percent Trace
I	Mg, SiO_2, SO_4	2.84	35.50%
II	Ca, Cl	2.48	30.96%
III	Na, HCO_3	1.56	19.47%

Factor-I is heavily loaded with Ca, Mg, Na, Cl and EC in Pre-Monsoon period and with Mg, SiO_2, and SO_4 in Post-Monsoon period. Factor-II is heavily loaded with SO_4 only in Pre-Monsoon and Ca and Cl in Post-Monsoon. Moreover, Factor-III is loaded with HCO_3 in Pre- and HCO_3 with Na in Post-Monsoon period (Fig.3 a & b). Hence, the trends of this three factors are more or less similar to those of Principal Components.

1.5 CLUSTER ANALYSIS:

1.5.1Correlation Coefficient Method:

Cluster analysis was carried out in this study to substantiate the interpretation of the hydro geological data. Basic statistics of hydro chemical data of ground water samples for both the seasons (i.e., Pre- and Post-Monsoon) are given in table.1. a&b, to understand the inter relations among the chemical constituents. A 8 X 8 matrix of correlation coefficient was computed using 'STATISTICA', a statistical software to carry out cluster analysis. Table-5. a&b provides the linear correlation coefficients of different chemical constituents of Pre-Monsoon ground water samples. Based on the correlation coefficients, similar pair of chemical constituent values were linked and then the next most similar pair and so on, until all the chemical constituents were clustered in the dendrogram (Fig.4 a&b) by arithmetic averaging method (Davis, 1973)

In the first step of the cluster analysis mutually highest correlation value in each column of the matrix was identified for pre-monsoon water samples as shown in the table-6 a, in bold face type. Next, similar highest correlation coefficient of chemical constituents of SiO_2-EC were clustered first. The new correlation co efficient between SiO_2-EC cluster and independent constituents were recalculated by arithmetic averaging method. The rest of the correlation coefficients of individual constituents were retained as they are (Table-6 b). Cl and SiO_2-EC were clustered as a single element. New correlation coefficients between SiO_2-EC-Cl and other independent constituents were recalculated by arithmetic averaging procedure (Table-6 c). SO_4 and SiO_2-EC-Cl are clustered as a single unit. Next Mg is clustered with SiO_2-EC-Cl-SO_4 as a unit and in the subsequent step Na and HCO_3 are clustered as another unit (Table-6 d). Finally these two individual clusters SiO_2-EC-Cl-SO_4-Mg and Na-HCO_3 were clustered (Table-6.e). Stepwise denderogram was constructed according to the step correlation matrix as shown in Fig.4a.

The same clustering procedure was repeated for post-monsoon ground water samples; mutually high pairs are sought out and clustered (Table-7.). The complete dendrogram for post-monsoon water samples was then constructed (Fig. 4b).

Only two clusters (i.e., SiO_2-EC-Ca-Cl-SO_4-Mg and Na-HCO_3) and three clusters (i.e., Ca-Cl-EC-SiO_2-Mg: Na-HCO_3 and SO_4) were formed for the pre and post-monsoon ground water samples respectively.

Cluster	Pre-monsoon	Post-monsoon
I	SiO_2-EC-Ca-Cl-SO_4-Mg (mixed water)	Ca-Cl-EC-SiO_2-Mg (Chloride water)
II	Na-HCO_3 (carbonate water)	Na-HCO_3 (Carbonate water)
III	--	SO_4 (sulphate water)

1.5.2 Distance measures:

Our criteria for linking two objects to form a cluster requires that both should have mutually the highest correlation with each other. A simple method is known as single linkage clustering, which connects objects to clusters on the basis of highest similarity between the object and any other object in the cluster. Results of clustering the distance matrix for both the seasons are given in Tables- 8 and 9, by single linkage are shown in figures 5 a and b. This single linkage clustering does not require an understanding of matrix algebra or an extensive background in multivariate statistics. Instead, the method is based on a simple rule of how to search a similarity matrix and when to combine cases.

In this method three clusters are identified in each monsoon season,

Cluster	Water type	Pre-monsoon	Post-monsoon
I	Chloride water	Ca-Na-Cl	Ca-Cl
II	Sulphate water	Mg-SiO_2-SO_4	Mg-SiO_2-Na-SO_4
III	Carbonate water	HCO_3	HCO3

1.5.3VALIDATION TECHNIQUE:

Five techniques are present for validating a cluster analysis, they are: 1) The cophenetic correlation, 2) significance tests on variables used to create clusters, 3) replication, 4) significance tests on independent variables, and 5) Monte carlo procedure.

Sokal and Rohlf (1962) first proposed the cophenetic correlation, and it is the major validation measure advocated by numerical taxonomists (Sneath and Sokal, 1973). The cophenetic correlation is used to determine how well the tree or dendrogram resulting from a cluster analysis actually represents the pattern of similarities and dissimilarities among the entities.

Volume : 3 | Issue : 11 | November 2014 • ISSN No 2277 - 8179

The cophenetic correlation is nothing but the matrix of apparent correlation contained within the dendrogram. By using the dendrogram for pre-monsoon it is possible to create an implied similarity matrix that shows the similarities between all pairs of entities as suggested by this hierarchical solution (Table-10 a and b). The degree of distortion is visualized in the dendrogram by plotting elements in the cophenetic values matrix against elements in the original correlation matrix (Fig.6 a and b). According to Davis (1973) if the two matrices are identical the plot would form a straight line. The correlation expressed in the dendrogram is too high if the points fall above the line and too low if they are below the line. A numerical measure of the similarity between the two matrices can be found simply by computing the correlation between equivalent elements. Only of the matrices either above or below the diagonal need be used as both the matrices are symmetrical.

1.6 Conclusion

In groundwater quality analysis the use of factor and cluster analysis gained momentum in identifying the various types. The principal component analysis and rotated factor matrix methods are applied in factor analysis. Based on these analyses, the leading chemical constituents are Mg, Ca, Na, Cl, and EC in in pre- and Mg, SiO_2, and SO_4 in post monsoon soon. Based on cluster analysis two distinct types of ground water in pre monsoon and three types in post monsoon are identified. Cluster -1 is characterized by SiO_2- EC-Cl-Ca-SO_4-Mg(mixed type) and cluster -2 by Na-HCO_3(Carbonate water) in pre moon soon; while in post monsoon Cluster -1 is influenced by Ca- Cl-EC-SiO_2-Mg(chloride water),cluster-2 by Na –HCO_3(carbonate water , cluster -3 by SO_4 (sulphate water). On the whole two clusters in pre monsoon and three clusters in post monsoon as shown in the dendograms indicate that the groundwater of the study area has temporary hardness in the pre monsoon and permanent hardness in the post monsoon.

Table-1a. Chemical analysis data of groundwater samples (mg/l) (pre-monsoon)

S. No.	Ca	Mg	Na+K	SiO_2	CO_3	HCO_3	SO_4	Cl	F	EC	PH	TDS (mg/l)
	--------------------mg/l----------------------											
1	66	13	88	05	32	332	10	50	1.6	618	8.2	428
2	76	27	80	10	24	432	15	48	1.5	756	8.3	493
3	76	14	95	10	55	304	20	66	1.8	785	8.3	426
4	32	07	57	05	-	192	10	46	1.6	436	7.7	257
5	68	11	105	10	24	400	10	46	0.9	724	8.3	471
6	22	04	177	20	51	392	10	28	2.0	810	8.4	503
7	76	21	182	28	24	488	25	148	1.8	1210	8.4	547
8	60	15	99	10	39	336	15	50	1.5	756	8.3	454
9	42	23	147	15	24	344	25	122	1.5	926	8.4	560
10	76	16	133	10	16	384	20	52	1.2	724	8.2	462
11	78	15	137	20	47	416	15	84	1.2	972	8.4	601
12	80	20	121	18	32	448	15	76	1.8	867	8.3	583
13	40	15	143	15	47	310	60	15	1.8	837	8.4	512
14	64	08	117	25	63	240	25	84	1.8	1020	8.8	626
15	72	14	109	15	24	392	15	68	1.7	860	8.3	510
16	48	12	124	10	43	376	10	34	2.2	726	8.3	466
17	108	23	49	05	43	348	15	70	1.0	734	8.2	485
18	144	32	46	18	51	408	25	104	1.0	952	8.3	621
19	152	37	85	28	12	384	50	234	1.8	1367	8.2	787
20	84	17	117	15	39	432	10	74	1.8	956	8.4	569
21	84	03	62	28	-	204	25	80	0.8	652	7.8	389
22	104	07	105	10	24	444	10	71	0.8	880	8.3	551
23	72	19	113	15	24	376	15	98	0.8	857	8.3	541
24	84	29	76	15	59	360	10	64	0.7	820	8.3	514
25	100	15	51	05	39	368	10	32	0.9	690	8.3	433
26	80	31	35	10	-	300	10	104	0.8	671	7.5	418
27	96	04	72	10	24	344	15	54	0.9	643	8.3	443
28	72	08	107	15	-	152	100	152	1.5	814	7.5	529
29	122	29	131	28	39	344	100	182	1.5	1295	8.2	740
30	104	19	137	25	63	344	20	160	1.2	1145	8.3	698
31	30	18	59	10	-	260	05	42	1.2	429	7.8	287
32	68	05	109	10	20	400	05	44	1.8	792	8.4	458
33	120	04	90	10	39	364	05	100	2.6	900	8.2	552
34	44	14	96	10	12	320	15	56	2.4	672	8.3	405
35	66	29	76	10	24	376	10	60	2.0	720	7.8	463
36	10	46	55	10	-	328	25	28	1.8	521	7.7	336
37	125	04	100	12	-	400	20	140	1.9	910	7.4	598
38	50	09	79	05	16	280	05	52	2.0	560	8.2	324
39	60	17	136	15	24	428	15	78	2.6	912	8.3	556
40	68	37	106	20	35	456	15	72	2.0	910	8.3	578
41	52	35	85	10	32	416	15	36	1.8	683	8.2	470

Table-1b. Chemical analysis data of groundwater samples (mg/l) (post-monsoon)

S. No.	Ca	Mg	Na+K	SiO_2	CO_3	HCO_3	SO_4	Cl	F	EC	PH	TDS (mg/l)
	--------------------mg/l----------------------											
1	100	11	27	5	-	336	15	44	0.9	578	7.5	368
2	52	17	78	5	-	256	15	44	1.2	532	7.4	337
3	48	10	72	10	-	296	15	44	1.4	556	7.7	345
4	42	20	31	5	-	224	5	44	1.2	405	7.7	257
5	92	22	45	10	-	400	15	60	0.8	712	7.2	441
6	16	10	143	18	31	399	10	20	1.6	655	8.4	429
7	68	36	102	25	24	416	25	118	1.6	915	8.2	591
8	80	6	56	10	-	328	15	44	1.2	583	7.7	373
9	98	16	75	15	-	408	15	88	1.5	816	7.4	508
10	92	20	23	5	-	352	20	44	0.9	596	7.4	378
11	58	23	75	15	-	368	15	60	1.2	693	7.4	624
12	94	3	10	10	-	272	5	20	1.5	409	7.7	276
13	48	20	46	10	-	312	5	60	1.2	612	7.8	363

S. No.	Ca	Mg	Na+K	SiO_2	CO_3	HCO_3	SO_4	Cl	F	EC	PH	TDS (mg/l)
	--------------------mg/l----------------------											
14	164	2	21	20	-	248	30	162	1.8	816	7.5	521
15	90	25	53	12	-	408	5	60	1.6	695	7.4	446
16	48	12	67	5	-	312	5	40	1.8	519	7.8	331
17	128	2	32	5	-	336	25	68	0.8	715	7.4	426
18	100	2	45	15	-	360	5	40	1.0	621	7.8	384
19	130	16	23	18	-	380	5	88	2.0	695	8	467
20	100	15	57	10	-	408	5	68	1.6	692	7.9	456
21	100	3	5	5	-	208	5	68	0.8	428	7.6	259
22	183	5	70	5	-	416	30	182	1.2	1020	7.4	680
23	82	32	44	10	-	344	20	92	0.9	723	7.4	450
24	104	18	43	15	-	404	5	64	0.8	710	7.8	448
25	100	5	9	5	-	332	5	24	0.9	482	7.5	312
26	104	15	7	10	-	264	5	82	1.2	546	7.3	353
27	90	8	50	10	-	328	30	44	1.4	651	7.7	394
28	94	13	24	10	-	120	30	150	1.8	567	7.5	380
29	238	1	8	25	-	384	40	184	1.2	1127	7.6	685
30	46	15	42	5	12	236	20	32	1.4	416	8.1	276
31	120	32	40	25	-	352	25	144	1.0	892	7.4	560
32	60	18	52	10	-	344	5	38	1.4	537	7.7	353
33	72	38	55	10	24	360	25	68	1.8	732	7.9	469
34	66	16	66	10	-	344	5	62	2.0	637	7.7	405
35	84	47	62	12	-	289	5	56	2.5	1100	7.5	700
36	10	46	55	5	-	328	25	28	2.0	521	7.8	336
37	125	4	100	12	-	400	20	140	2.0	910	7.4	598
38	72	13	14	5	-	220	5	56	1.6	426	8.1	273
39	90	22	75	12	-	432	10	80	2.0	791	7.9	502
40	108	10	44	15	-	368	20	60	1.8	732	7.5	448
41	64	5	95	5	-	384	5	48	1.8	627	7.7	411

Table -2a. Factor analysis-Principal Components
Pre-monsoon

Variable	Factor-1	Factor-2	Factor-3
Ca	0.786584	0.059096	0.059529
Mg	0.813616	0.115657	0.119430
Na	0.716607	-0.139420	-0.019578
SiO_2	0.593550	-0.371105	0.159467
HCO_3	0.100070	-0.483631	-0.846739
SO_4	0.173094	0.776089	-0.498667
CI	0.759785	0.185545	0.044832
EC	0.703574	-0.067255	-0.125536
Expl. Var.	3.258776	1.049189	1.026981
Prop. Total	0.407347	0.131149	0.128373

Post-Monsoon

Variable	Factor-1	Factor-2	Factor-3
Ca	-0.059035	0.888674	0.354511
Mg	-0.811488	-0.199010	-0.262990
Na	-0.274397	-0.099192	-0.878965
SiO_2	-0.928669	0.105005	-0.086759
HCO_3	0.503868	0.391894	-0.653725
SO_4	-0.902077	0.253117	0.043304
Cl	-0.288239	0.868791	0.117272
EC	0.299844	0.808930	-0.373473
Expl. Var.	2.840331	2.477026	1.557415
Prop. Total	0.355041	0.309628	0.194677

Table-2 b. Leading Chemical Constituents in Principal Component Analysis of Ground Water
Pre-Monsoon

Component	Leading Chemical Parameter	Eigen Value	Per cent trace
I	Mg, Ca, NaCl, EC	3.47	43.45
II	SO_4	1.51	18.89
III	HCO_3	1.35	16.87

Post-Monsoon

Component	Leading Chemical Parameter	Eigen Value	Per cent trace
I	Mg, SiO_2, SO_4	2.84	35.50
II	Ca, Cl, EC	2.47	30.96
III	Na, HCO_3	1.56	19.47

Table-3: Factor Scores

	Pre-Monsoon			Post-Monsoon		
S. No.	Factor-1	Factor-2	Factor-3	Factor-1	Factor-2	Factor-3
1	-0.973	0.018	0.039	-0.462	-0.635	-0.365
2	-0.353	-0.413	1.065	-0.921	0.144	0.511
3	-0.316	0.158	-0.114	-0.643	0.217	-0.096
4	-1.806	1.417	-0.953	-1.473	-0.55	0.828
5	-0.53	-0.675	-0.109	0.107	0.429	-0.091
6	0.128	-2.065	-2.064	-0.368	2.305	-1.255
7	1.976	-1.651	-0.681	1.455	2.048	1.161
8	-0.527	-0.216	-0.211	-0.369	-0.146	-0.642
9	0.492	-0.369	-0.887	0.699	0.811	-0.579
10	-0.462	0	0.271	-0.359	-0.368	0.342
11	0.67	-1.142	-0.308	0.034	1.042	0.229
12	0.409	-1.01	0.232	-1.402	-1.208	-0.762
13	-0.01	-0.187	-1.777	-0.66	0.271	0.219
14	0.595	0.182	-1.405	1.673	-1.769	0.479
15	0.04	-0.536	-0.162	-0.038	0.799	-0.387
16	-0.622	-1.018	-0.586	-1.086	0.245	-0.496
17	-0.501	0.657	1.557	0.263	-1.032	-0.599
18	0.848	0.627	2.315	-0.182	-0.133	-1.531
19	2.828	1.449	1.498	0.512	-0.208	-0.665
20	0.348	-1.034	0.308	0	0.465	-1.056
21	-0.093	1.745	-1.187	-1.001	-1.861	-0.185
22	0.047	-0.769	0.378	2.01	-0.53	-0.852
23	0.226	-0.304	-0.037	0.245	0.332	1.271
24	-0.046	-0.129	1.11	0.18	0.432	-1.774
25	-0.873	0.206	1.177	-0.947	-0.986	-1.077
26	-0.539	1.13	1.333	-0.429	-1.123	0.219
27	-0.655	0.361	0.067	0.086	-0.335	-0.061

28	0.742	3.093	-2.407	0.201	-1.985	2.269
29	2.813	1.442	-0.508	3.336	-1.612	-0.309
30	1.632	-0.278	-0.138	-1.168	-0.591	0.911
31	-1.562	0.871	-0.325	1.703	0.322	1.506
32	-0.516	-0.854	-0.367	-0.773	0.387	-0.309
33	0.111	-0.053	0.462	0.191	0.817	1.633
34	-0.769	0.101	-0.587	-0.428	0.507	-0.448
35	-0.505	-0.038	0.92	0.277	1.319	1.768
36	-1.199	0.693	0.709	-0.976	1.107	2.494
37	0.323	0.432	0.171	1.314	0.456	-1.172
38	-1.316	0.439	-0.43	-1.214	-1.204	0.404
39	0.274	-1.117	-0.365	0.396	1.119	-0.578
40	0.514	-0.945	1	0.463	-0.073	-0.46
41	-0.586	-0.519	0.998	-0.617	0.77	-1.62

Table-4.a Factor analysis- Rotated varimax Components Pre-Monsoon

Variable	Factor-1	Factor-2	Factor-3
Ca	0.787414	0.069617	-0.029706
Mg	0.818491	0.089261	-0.108212
Na	0.714819	-0.065157	0.134525
SiO_2	0.612690	-0.362452	0.093216
HCO_3	0.034507	0.023686	0.979351
SO_4	0.112621	0.930984	0.039091
Cl	0.756876	0.183886	-0.083869
EC	0.690923	0.050510	0.188075

Post-Monsoon

Variable	Factor-1	Factor-2	Factor-3
Ca	-0.033690	0.411870	-0.100937
Mg	0.317539	-0.108700	0.066174
Na	0.227292	-0.204254	0.485874
SiO_2	0.330851	0.047609	-0.008535
HCO_3	-0.073177	0.007725	0.476735
SO_4	0.302000	0.129303	-0.064489
Cl	0.080730	0.363475	0.018839
EC	-0.045956	0.228145	0.348048

Table-4.b: Leading Chemical Constituents Based on Rotated Factor Matrix for Ground Water

Pre-Monsoon

Component	Leading chemical Parameter	Eigen Value	Per cent trace
I	Ca, Mg, Na, Cl, EC	3.48	43.45
II	S04	1.51	18.89
III	HCO_3	1.35	16.87

Post-Monsoon

Component	Leading chemical Parameter	Eigen Value	Per cent trace
I	Mg, SiO_2, SO_4	2.84	35.50
II	Ca, Cl	2.48	30.96
III	Na,HCO_3	1.56	19.47

Table-5. a) Correlation coefficient values for pre-monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	0.06	-0.17	0.30	0.28	0.22	0.65	0.56
Mg	0.06	1.00	-0.23	0.16	0.27	0.15	0.19	0.22
Na	-0.17	-0.23	1.00	0.51	0.40	0.22	0.21	0.56
SiO_2	0.30	0.16	0.51	1.00	0.15	0.46	0.64	0.78
HCO_3	0.28	0.27	0.40	0.15	1.00	-0.31	-0.00	0.46
SO_4	0.22	0.15	0.22	0.46	-0.31	1.00	0.54	0.45
Cl	0.65	0.19	0.21	0.64	-0.00	0.54	1.00	0.74
EC	0.56	0.22	0.56	0.78	0.46	0.45	0.74	1.00

Table-5 b) Correlation co-efficient values for post-monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	-0.42	-0.41	0.38	0.19	0.45	0.75	0.60
Mg	-0.42	1.00	0.20	0.12	0.12	0.00	-0.09	0.20
Na	-0.41	0.20	1.00	0.16	0.50	-0.01	-0.08	0.28
SiO_2	0.38	0.12	0.16	1.00	0.37	0.30	0.51	0.62
HCO_3	0.19	0.12	0.50	0.37	1.00	0.02	0.09	0.55
SO_4	0.45	0.00	-0.01	0.30	0.02	1.00	0.62	0.48
Cl	0.75	-0.09	-0.08	0.51	0.09	0.62	1.00	0.69
EC	0.60	0.20	0.28	0.62	0.55	0.48	0.69	1.00

Table-6:Different steps of correlation matrix (Pre-Monsoon)
a) FIRST STEP

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	0.06	-0.17	0.30	0.28	0.22	0.65	0.56
Mg	0.06	1.00	-0.23	0.16	0.27	0.15	0.19	0.22
Na	-0.17	-0.23	1.00	0.51	0.40	0.22	0.21	0.56
SiO_2	0.30	0.16	0.51	1.00	0.15	0.46	0.64	0.78
HCO_3	0.28	0.27	0.40	0.15	1.00	-0.31	-0.00	0.46
SO_4	0.22	0.15	0.22	0.46	-0.31	1.00	0.54	0.45
Cl	0.65	0.19	0.21	0.64	-0.00	0.54	1.00	0.74
EC	0.56	0.22	0.56	0.78/	0.46	0.45	0.74	1.00

b) SECOND STEP

	SiO_2-EC	Ca	Mg	Na	HCO_3	SO_4	Cl
SiO_2-EC	1.00	0.43	0.19	0.54	0.32	0.46	0.69
Ca	0.43	1.00	0.06	-0.17	0.28	0.22	0.65
Mg	0.19	0.06	1.00	-0.23	0.27	0.15	0.19
Na	0.54	-0.17	-0.23	1.00	0.40	0.22	0.21
HCO_3	0.32	0.28	0.27	0.40	1.00	-0.31	-0.00
SO_4	0.46	0.22	0.15	0.22	-0.31	1.00	0.54
Cl	0.69	0.65	0.19	0.21	-0.00	0.54	1.00

c) THIRD STEP

	SiO_2-EC-Cl	Ca	Mg	Na	HCO_3	SO_4
SiO_2-EC-Cl	1.00	0.54	0.19	0.47	0.16	0.50
Ca	0.54	1.00	0.06	-0.17	0.28	0.22
Mg	0.19	0.06	1.00	-0.23	0.27	0.15
Na	0.47	-0.17	-0.23	1.00	0.40	0.22
HCO_3	0.16	0.28	0.27	0.40	1.00	0.31
SO_4	0.50	0.22	0.15	0.22	-0.31	1.00

d) FOURTH STEP

	SiO_2-EC-Cl-Ca	Mg	Na	HCO_3	SO_4
SiO_2-EC-Cl-Ca	1.00	0.12	0.15	0.22	0.36
Mg	0.12	1.00	-0.23	0.27	0.15
Na	0.15	-0.23	1.00	0.40	0.22
HCO_3	0.22	0.27	0.40	1.00	-0.31
SO_4	0.36	0.15	0.22	-0.37	1.00

e) FIFTH STEP

	SiO_2-EC-Cl-Ca-SO_4	Na-HCO_3	Mg
SiO_2-EC-Cl-Ca-SO_4	1.00	0.13	0.14
Na-HCO_3	0.13	1.00	0.02
Mg	0.14	0.02	1.00

f) SIXTH STEP

	SiO_2-EC-Cl-Ca-SO_4-Mg	Na-HCO_3
SiO_2-EC-Cl-Ca-SO_4-Mg	1.00	0.08
Na-HCO_3	0.08	1.00

Table-7: Different steps of correlation matrix(Post-Monsoon)

a) FIRST STEP

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	-0.42	-0.41	0.38	0.19	0.45	0.75	0.60
Mg	-0.42	1.00	0.20	0.12	0.12	0.00	-0.09	0.20
Na	-0.41	0.20	1.00	0.16	0.50	-0.01	-0.08	0.28
SiO_2	0.38	0.12	0.16	1.00	0.37	0.30	0.51	0.62
HCO_3	0.19	0.12	0.50	0.37	1.00	0.02	0.09	0.55
SO_4	0.45	0.00	-0.01	0.30	0.02	1.00	0.62	0.48
Cl	0.75	-0.09	-0.08	0.51	0.09	0.62	1.00	0.69
EC	0.60	0.20	0.28	0.62	0.55	0.48	0.69	1.00

b) SECOND STEP

	Ca-Cl	Mg	Na	SiO_2	HCO_3	SO_4	EC
Ca-Cl	1.00	-0.26	-0.25	0.45	0.14	0.54	0.65
Mg	-0.26	1.00	0.20	0.12	0.12	0.00	0.20
Na	-0.25	0.20	1.00	0.16	0.50	-0.01	0.28
SiO_2	0.45	0.12	0.16	1.00	0.37	0.30	0.62
HCO_3	0.14	0.12	0.50	0.37	1.00	0.02	0.55
SO_4	0.54	0.00	-0.01	0.50	0.02	1.00	0.48
EC	0.65	0.20	0.28	0.62	0.55	0.48	1.00

c) THIRD STEP

	Ca-Cl-EC	Mg	Na	SiO_2	HCO_3	SO_4
Ca-Cl-EC	1.00	-0.30	-0.02	0.54	0.35	0.51
Mg	-0.30	1.00	0.20	0.12	0.12	0.00
Na	-0.02	0.20	1.00	0.16	0.50	-0.01
SiO_2	0.54	0.12	0.16	1.00	0.37	0.30
HCO_3	0.35	0.12	0.50	0.37	1.00	0.02
SO_4	0.51	0.00	-0.01	0.50	0.02	1.00

d) FOURTH STEP

	Ca-Cl-EC- SiO_2	Mg	Na-HCO_3	SO_4
Ca-Cl-EC-SiO2	1.00	0.45	0.31	0.41
Mg	0.45	1.00	0.16	0.002
Na-HCO_3	0.31	0.16	1.00	0.005
SO_4	0.41	0.005	0.00	1.00

e) FIFTH STEP

	Ca-Cl-EC-SiO_2- Mg	Na-HCO_3	SO_4
Ca-Cl-EC-SiO_2-Mg	1.00	0.24	0.21
Na-HCO_3	0.24	1.00	0.005
SO_4	0.21	0.005	1.00

f) SIXTH STEP

	Ca-Cl-EC-SiO_2-Mg- Na-HCO_3	SO_4
Ca-Cl-EC-SiO_2-Mg- Na-HCO_3	1.00	0.11
SO_4	0.11	1.00

Table-8.a) Euclidean distances for pre-monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	000	420	350	433	20E2	407	223	48E2
Mg	420	000	571	78	24E2	142	482	52E2
Na	350	571	000	576	19E2	548	351	47E2
SiO_2	433	78	576	000	24E2	127	490	53E2
HCO_3	20E2	24E2	19E2	24E2	000	24E2	21E2	30E2
SO_4	407	142	548	127	24E2	000	443	52E2
Cl	223	482	351	490	21E2	443	000	48E2
EC	49E2	52E2	47E2	53E2	30E2	52E2	48E2	000

B) Amalgamation schedule of Euclidean distances for pre-monsoon (single linkage)

Linkage distance	1	2	3	4	5	6	7	8
77.698	Mg	SiO_2	--	--	--	--	--	--
127.212	Mg	SiO_2	SO_4	--				--
223.468	Ca	Cl	--	--	--	--	--	--
350.359	Ca	Cl	Na	--	--	--	--	--
407.106	Ca	Cl	Na	Mg	So_2	SO_4	--	--
1892.347	Ca	Cl	Na	Mg	So_2	SO_4	HCO_3	--
2962.195	Ca	Cl	Na	Mg	So_2	SO_4	HCO_3	EC

Table-9.a) Euclidean distances for post-monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	000	559	458	562	13E2	537	223	38E2
Mg	559	000	286	85	21E2	97	456	43E2
Na	458	286	000	310	19E2	300	368	41E2
SiO_2	562	85	310	000	21E2	66	462	43E2
HCO_3	16E2	21E2	19E2	21E2	000	21E2	18E2	23E2
SO_4	537	97	300	66	21E2	000	434	43E2
Cl	223	456	368	462	18E2	434	000	39E2
EC	38E2	43E2	41E2	43E2	23E2	43E2	39E2	000

b) Amalgamation schedule of Euclidean distances for post-monsoon (single linkage)

Linkage distances	1	2	3	4	5	6	7	8
66.166	So_2	SO_4						
85.117	Mg	SiO_2	SO_4					
223.002	Ca	Cl						
286.372	Mg	SiO_2	SO_4	Na				
368.137	Ca	Cl	Mg	SiO_2	SO_4	Na		
1632.328	Ca	Cl	Mg	SiO_2	SO_4	Na	HCO_3	
2346.061	Ca	Cl	Mg	SiO_2	SO_4	Na	HCO_3	EC

Table-10: Matrix of cophenetic correlations derived from dendrogram

Pre-Monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	0.14	0.08	0.54	0.08	0.36	0.54	0.54
Mg	0.14	1.00	0.08	0.14	0.08	0.14	0.14	0.14
Na	0.08	0.08	1.00	0.08	0.40	0.08	0.08	0.08
SiO_2	0.54	0.14	0.08	1.00	0.08	0.36	0.69	0.78
HCO_3	0.08	0.08	0.40	0.08	1.00	0.08	0.08	0.08
SO_4	0.36	0.14	0.08	0.36	0.08	1.00	0.36	0.36
Cl	0.54	0.14	0.08	0.69	0.08	0.36	1.00	0.69
EC	0.54	0.14	0.08	0.78	0.08	0.36	0.69	1.00

Post-Monsoon

	Ca	Mg	Na	SiO_2	HCO_3	SO_4	Cl	EC
Ca	1.00	0.45	0.24	0.54	0.24	0.005	0.75	0.65
Mg	0.45	1.00	0.24	0.45	0.24	0.005	0.45	0.45
Na	0.24	0.24	1.00	0.24	0.50	0.005	0.24	0.24
SiO_2	0.54	0.45	0.24	1.00	0.24	0.005	0.54	0.54
HCO_3	0.24	0.24	0.50	0.24	1.00	0.005	0.24	0.24
SO_4	0.005	0.005	0.005	0.005	0.005	1.00	0.005	0.005
Cl	0.75	0.45	0.24	0.54	0.24	0.005	1.00	0.65
EC	0.65	0.45	0.24	0.54	0.24	0.005	0.65	1.00

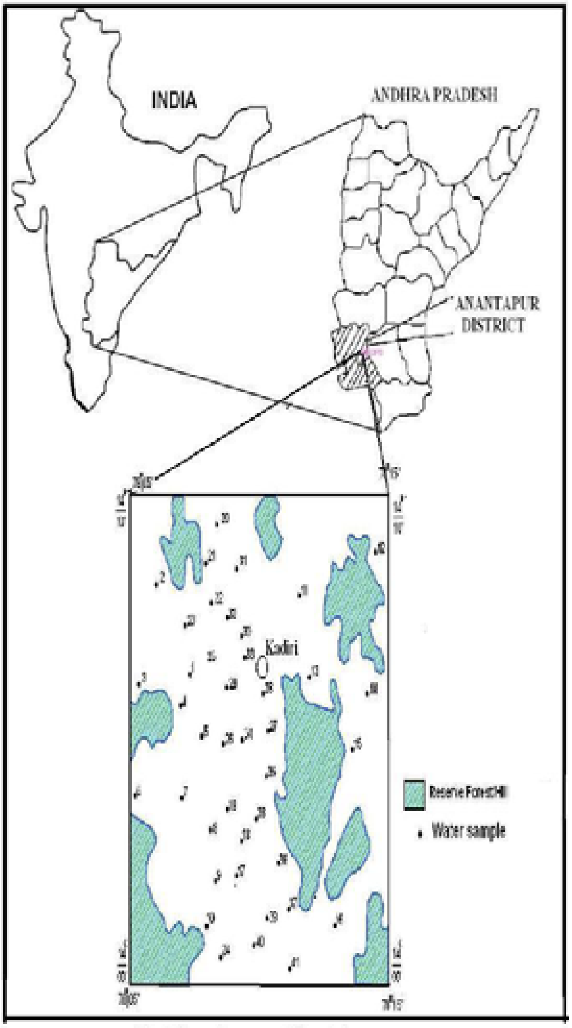


Fig.1 Location map of the study area

Fig.2 Geological map of of the study area

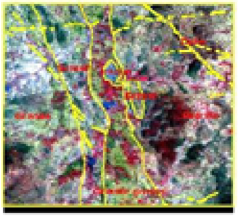
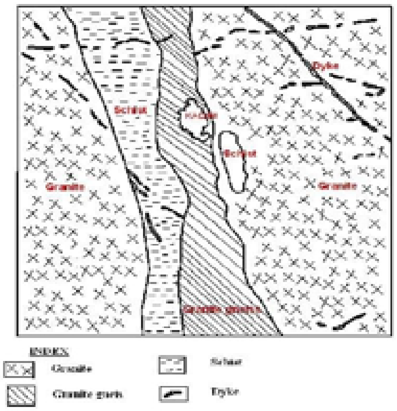


Fig. 2 Geological map of the study area



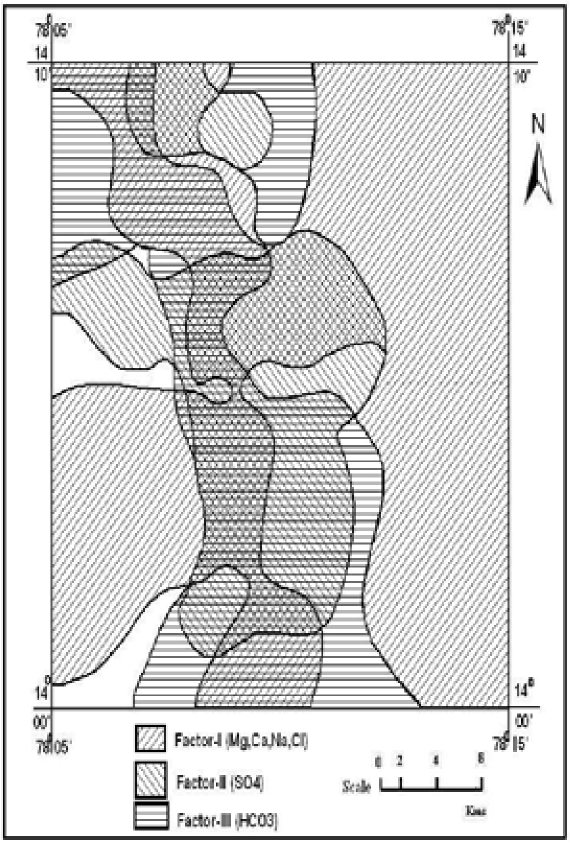


Fig. 3a Map showing distribution of factors 1, 2 & 3 for premonsoon

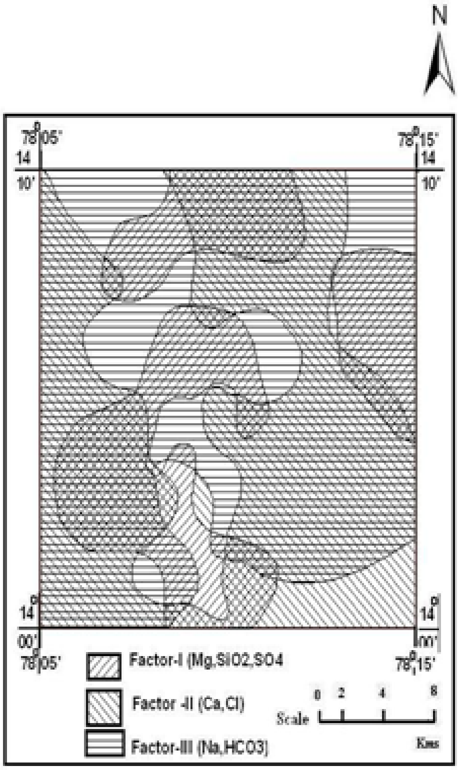


Fig. 3b Map showing distribution of factors 1, 2 & 3 for postmonsoon

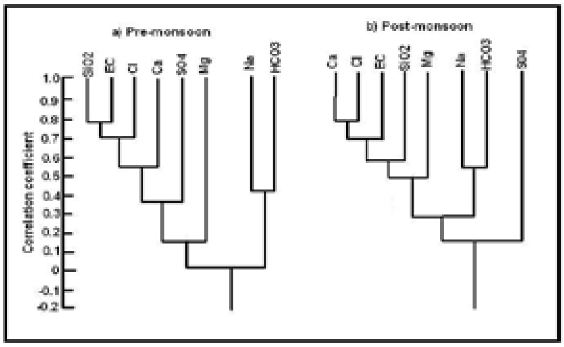


Fig. 4 Dendrogram showing various clusters for pre- and post-monsoon

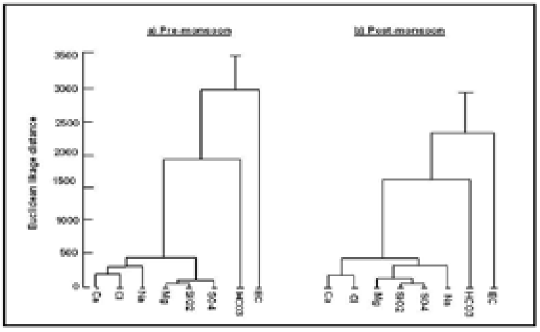


Fig.5 Dendrogram showing Euclidean linkage distance for pre and post-monsoon

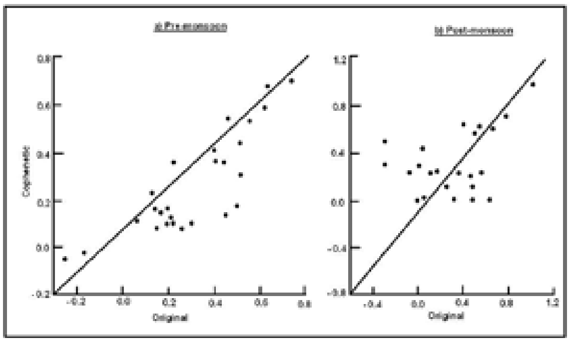


Fig.6 Diagram showing the validation of cluster analyses for Pre-and Post-monsoon

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