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The cluster analysis approach for classification of Andhra Pradesh on the basis of rainfall

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सार — आंध्र प्रदेश के जिलों को, विभिन्न ऋतुओं में रिकार्ड की गई मासिक वर्षा के आधार पर, वर्गीकृत करने के लिए गुच्छ विश्लेषण की औसत संयोजन पद्धति का प्रयोग किया गया। इसके अंतर्गत गुच्छ निर्माण में सबसे कम अवास्तविकता होती है जो कि मुख्य संघटक पद्धति में नहीं होती। 1961-62 से 1990-91 तक 30 वर्षों की मासिक वर्षा के आंकड़ों से ऋतुवार विश्लेषण किया गया। यह ज्ञात हुआ कि आंध्र प्रदेश के जिलों को 5 से 7 समूहों में बांटा जा सकता है जो कि ऋतु पर निर्भर करते हैं। आंध्र प्रदेश के तटीय क्षेत्र के पूर्वी और पश्चिमी गोदावरी जिलों में सभी ऋतुओं के दौरान तथा तेलंगाना क्षेत्र के कुछ जिलों में दक्षिण-पश्चिम मानसून ऋतु को छोड़कर बाकी ऋतुओं में वर्षा के समान प्रतिमान पाए गए हैं। कुछ समूहों में ऐसी वर्षा होती है जैसी कि राज्य के सभी तीनों क्षेत्रों के जिलों में होती है। शोध-पत्र में ऋतुवार गुच्छ निर्माण पर भी चर्चा की गई है।

ABSTRACT. The average linkage method of cluster analysis was applied for classifying the districts of Andhra Pradesh on the basis of monthly rainfall recorded in different seasons. The method of clustering has the advantage of least subjectivity in cluster formation unlike that of the principal components method. The analysis was carried out seasonwise on the basis of 30 years of monthly rainfall data covering the years 1961-62 to 1990-91. It was found that the districts of Andhra Pradesh can be classified into 5 to 7 clusters which depend on the season. East and West Godavari districts of coastal Andhra region exhibited a similar pattern in the rainfall of all the seasons; certain districts of Telangana region also exhibited a similar pattern in rainfall of all the seasons excepting the southwest monsoon. In certain clusters, there was a representation of districts from all the three regions of the State. Seasonwise clusterings are also discussed.

Key words — Cluster analysis, Principal components.

1. Introduction

Delineation of regions (or districts) according to climatic variation is an important step in agricultural planning. Such classification helps in increasing the stability in the crop production. Due to the advent of computers, many advanced multivariate procedures such as the principal component analysis are being used for this purpose (Gadgil and Joshi 1980, Prabhakaran *et al.* 1992, Chowdhury *et al.* 1993). The approach has the limitation that it represents the larger differences among the objects (which are to be classified) fairly well but it distorts the differences between the closer objects (Rohlf 1970). Further, the formation of groups is subjective, *i.e.*, based on only the visual inspection of the two (or three) dimensional plot of the component scores of the objects (Sneath and Sokal 1973).

Contrary to the component analysis approach, a variety of methods which were developed only for classification purpose and listed under cluster analysis are available. The major advantage of these methods is that unlike the principal component analysis, the element of subjectivity in the formation of groups (clusters) is almost minimum. These methods are commonly applied in taxonomy. An application of these methods for classifying the 18 States of India based on agro-economic indicators is also available (Goel and Vasisht 1990). There seems to be no attempt at applying these methods for classifying the regions on the basis of climatic variations. In this study, an attempt has been made to classify the districts of Andhra Pradesh State on the basis of seasonal and annual rainfall (monthwise) by using a suitable method of clustering, *viz.*, the average linkage method.

2. The approach

The various methods of cluster analysis can be categorised into the following approaches :

(a) Hierarchical techniques, (b) Optimisation methods, (c) Density or mode seeking methods, (d) Clumping techniques, and (e) Ordination methods*. Among these approaches, the methods developed under hierarchical approach are commonly applied due to the advantage that the relative differences between the objects (classified within a group and those outside it) can be readily viewed through a tree diagram, known as the dendrogram.

Among the several methods in hierarchical approach, the single linkage or nearest-neighbour

*— For a detailed review of these methods one can refer Everitt (1974)

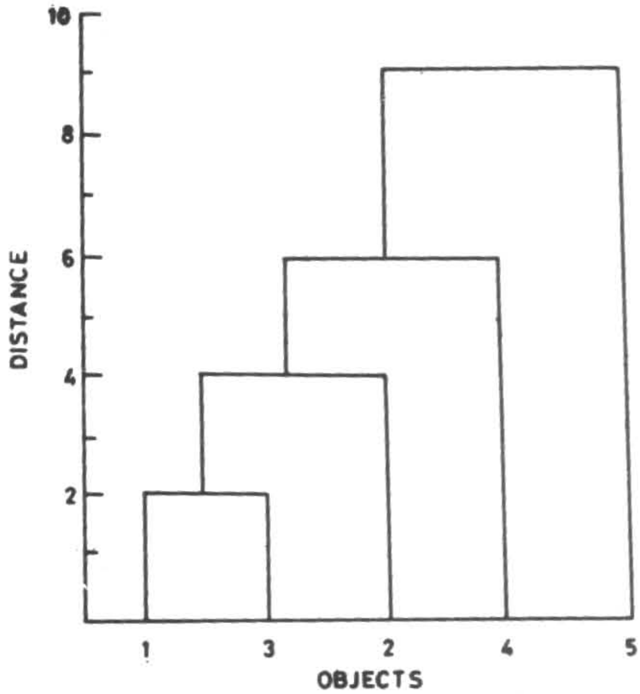


Fig. 1. Dendrogram of the hypothetical example

method has been advocated for application, as it was found to satisfy the properties such as :

(i) Invariant to transformations,

(ii) Powerful in estimating the true partitions when the true partitions include a single largest sub-set,

(iii) Set consistent,

(iv) Optimises the 'connected set of pairs, and

(v) Possesses the property of chaining and monotonicity

(Mardia *et al.* 1989, Baker & Hubert 1975 and Jardine & Sibson 1971).

In single linkage method (and also in hierarchical methods), the objects are classified on the basis of a criterion which is assumed to be measuring the similarity between the objects. A comparison of such similarity coefficients among the pairs of objects finally leads to a dendrogram. Thus the method groups the objects which are 'nearest' to one another in the following way :

Let there be k objects which are to be classified into different groups on the basis of a p variate observation vector $\mathbf{x}$. Let there be 'n' observations on each of these objects which are obtained by drawing a random sample of size n. The similarities among the objects are measured in the form of distances and the most commonly applied measure is the Mahalanobis' D^2-statistic (which is the generalised distance) :

$$D^2_{ij} = [\mathbf{x}^{(i)} - \mathbf{x}^{(j)}]\ S^{-1}\ [\mathbf{x}^{(i)} - \mathbf{x}^{(j)}],$$

$$\text{for } i \neq j = 1, \ldots, k$$

where, D^2_{ij} is the squared distance between the (i, j)th objects, $[\bar{\mathbf{x}}^{(i)}, \bar{\mathbf{x}}^{(j)}]$ are the mean vectors of (i, j)th objects and S is the matrix of pooled variance and covariance of the objects.

These inter-object distances (*i.e.*, d^2_{ij} or d_{ij}) form the distance matrix D. From D, the most closest pair of the objects (in terms of the least d_{ij}) is considered as the initial cluster. In the subsequent steps, the search for the next closest pair is continued not from the D matrix but from the revised D matrix which represents the distances of the initial cluster with the other objects along-with those already existing in the D matrix. The procedure can be explained from the following example in which 5 objects are to be classified into different clusters on the basis of their following distance matrix D :

D =

Objects	1	2	3	4	5
1	0	3	2	8	10
2	3	0	4	7	9
3	2	4	0	6	12
4	8	7	6	0	11
5	10	9	12	11	0

The initial cluster is obviously the pair of objects (1, 3) having the least distance ($d_{13} = 2$). The D matrix is then revised in terms of the distances of the initial cluster (*i.e.*, 1, 3) with the other objects as follows :

D_1 =

	(1, 3)	2	4	5
(1,3)	0	3	6	10
2	3	0	7	9
4	6	7	0	11
5	10	9	11	0

The distance of (1, 3) with any other object j in the D_1 is obtained from the criterion, $d_{(13)j} = \min [d_{1j}, d_{3j}]$. Proceeding in the similar way the next closest pair can be seen to be (1, 3) 2 whose distance = 3. Due to this choice, the revised distance matrix D_2 becomes :

D_2 =

	(1, 3, 2)	4	5
(1, 3, 2)	0	6	9
4	6	0	11
5	9	11	0

Here also, the distance of (1, 3, 2) with any other object say 4 is obtained from the same minimum d_{ij} criterion as follows :

$$d_{(132)4} = \min [d_{14}, d_{34}, d_{24}] = \min [8, 6, 7] = 6.$$

TABLE 1

Clustering of districts in Andhra Pradesh State

Cluster No.	Southwest monsoon	Northeast monsoon	Hot weather period	Overall period
1	EGD, WGD, HYD, KRSN, VZG, SRK	SRK, VZG, EGD	EGD, WGD	EGD, WGD, VZG, SRK
2	GNTR, MBNR, NLG	MBNR, KRMN, MDK, ADB, WGL, KHM, NLG	KRSN, CHTR, GNTR, KRNL, ANTP, KHM	GNTR, CDP, KRSN
3	CDP, CHTR, KRNL, NLR, ANTP	WGD, KRSN, GNTR, CDP, CHTR	NLR, CDP	MBNR, NLG, KRNL, HYD
4	NZB, ADB	KRNL, ANTP, HYD, NZB	HYD	CHTR
5	WGL, KRMN, KHM, MDK	NLR	NZB, ADB, NLG, KRMN, MDK, MBNR, WGL	ANTP
6	—	—	VZG	NZB, ADB, WGL, KRMN, MDK, KHM
7	—	—	SRK	NLR

SRK — Srikakulam, VZG — Visakhapatnam, EGD — East Godavari, WGD — West Godavari, KRSN — Krishna, GNTR — Guntur, NLR — Nellore, KRNL — Kurnool, ANTP — Anantapur, CDP — Cuddapah, CHTR — Chittoor, HYD — Hyderabad, NZB — Nizamabad, MDK — Medak, MBNR — Mehboobnagar, NLG — Nalagonda, WGL — Warangal, KHM — Khammam, KRMN — Karimnagar, ADB — Adilabad.

Finally, the closest pair in D_2 is (1, 3, 2, 4), $[d_{(132)4} = 6]$ so that there are two clusters (1, 3, 2, 4) and (5). The new distance matrix during this step is :

$$D_3 = \begin{array}{ccc} & (1,3,2,4) & 5 \\ (1,3,2,4) & 0 & 9 \\ 5 & 9 & 0 \end{array}$$

The distance matrix during each step of search serves as a base for cluster formation, *i.e.*, these matrices provide 'links' for the clusters (that are existing) with the other objects. These can be conveniently represented in the form of a dendrogram (tree diagram) by taking the objects, *i.e.*, the order in which they are screened on X-axis and the corresponding distances on Y-axis. The dendrogram of the above numerical example is presented in Fig. 1. Cluster formation can be viewed from this diagram by taking some threshold distance d_0, *i.e.*, clusters can be formed such that the inter-cluster distances of all the clusters are $\geqslant d_0$. The choice of d_0 is arbitrary and depends on how close the clusters are to be formed. In the above example if d_0 is fixed at 6.0, then there can be two clusters, *viz.*, (1, 3, 2, 4) and (5); similarly, setting d_0 at 4.0 leads to three clusters, *viz*, (1, 3, 2), (4) and (5) (Fig. 1). It is thus obvious that the element of subjectivity in this approach is involved only to the extent of choice of d_0.

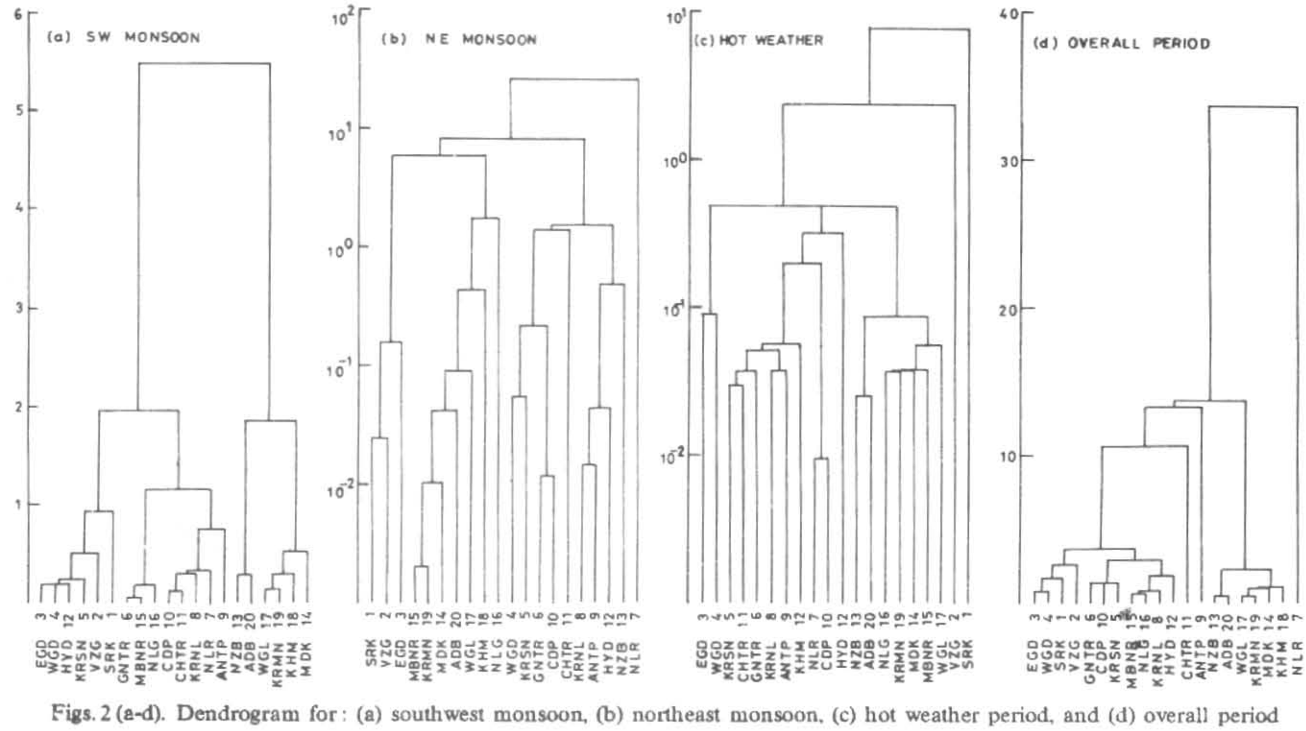
The major limitation of the above approach is that during any step for the search of cluster, the distance of the cluster already existing in the step with the other objects is obtained on the basis of the minimum distance criterion. Such computation would lead to extremities. These extremities can be refined by taking the average of the distance of the objects, instead of the relatively minimum value. This, essentially, is the approach involved in the average linkage method. The average linkage method was found to be useful in representing the true partitions in a better way as compared to the single linkage method (Sokal and Sneath 1963). Further, it was found to be useful when "a formal non-overlapping hierarchy is desired" (Sneath and Sokal 1973). For illustrating the average linkage method, the same distance matrix can be considered. The revised distance matrices in the subsequent steps of search are as follows :

$$D_1 = \begin{array}{ccccc} & (1,3) & 2 & 4 & 5 \\ (1,3) & 0 & 3.5 & 7.0 & 11.0 \\ 2 & 3.5 & 0 & 7.0 & 9.0 \\ 4 & 7.0 & 7.0 & 0 & 11.0 \\ 5 & 11.0 & 9.0 & 11.0 & 0 \end{array}$$

e.g., $d_{(13)2} = [d_{12} + d_{32}]/2 = (3 + 4)/2 = 3.5$

$$D_2 = \begin{array}{cccc} & (1,3,2) & 4 & 5 \\ (1,3,2) & 0 & 7.0 & 10.3 \\ 4 & 7.0 & 0 & 11.0 \\ 5 & 10.3 & 11.0 & 0 \end{array}$$

e.g., $d_{(132)4} = [d_{14}+d_{34}+d_{24}]/3 = (8+6+7)/3 = 7.0.$



Figs. 2 (a-d). Dendrogram for: (a) southwest monsoon, (b) northeast monsoon, (c) hot weather period, and (d) overall period

$$D_3 = \begin{array}{c|cc} & (1,3,2,4) & 5 \\ \hline (1,3,2,4) & 0 & 10.2 \\ 5 & 10.2 & 0 \end{array}$$

For the above example, incidently both the approaches lead to the same clusterings (and the objects within them), for the respective thresholds (d_0) of 7.0 and 3.5. However, the inter-cluster distances are different.

3. Data

In the present study, the average linkage method is applied for classifying the 20 districts of Andhra Pradesh State on the basis of 30 years of monthly rainfall data covering the years 1961-62 to 1990-91.* The classification was obtained corresponding to the rainfall of the following seasons :

S. No.	Season	Variables (monthly rainfall)
1	Southwest monsoon	June-September (4 months)
2	Northeast monsoon	October-December (3 months)
3	Hot weather period	March-May (3 months)
4	Overall	June-May (12 months)

Winter season (January-February) was not considered for classification, as in most of the years the rainfall during these months was zero

* A. P. State comprises of 23 districts. Out of these, 3 districts, *viz.* Prakasam, Vizianagaram and Ranga Reddy were formed in the later years. Hence complete data were available only for the 20 districts.

Thus for the classification corresponding to the southwest monsoon rainfall, the analysis is based on the observation vector '**x**' which comprises of 4 rainfall variables, *i.e.,* June to September. Similarly, the number of variables involved in the analysis of other seasons is indicated in the above table.

The relevant data were collected from the Season and Crop Reports and Statistical Abstracts of Andhra Pradesh State.

4. Results and discussion

The average rainfall of the 20 districts of Andhra Pradesh State (over 30 years) recorded under the different months of the season is presented in Table 2. The districts of Andhra Pradesh State are divided into three administrative regions, *viz.,* Coastal Andhra (districts 1 to 7), Rayalaseema (districts 8 to 11) and Telangana (districts 12 to 20). As can be seen (Table 2), there is a considerable spatial variation in the rainfall received during the different seasons.

Southwest monsoon — July and August can be seen to be the peak rainfall months of this season in all the districts of coastal Andhra and Telangana regions. Nizamabad district of Telangana region recorded the highest average rainfall of 305 mm during August. However, in Rayalaseema region, it is the September month which recorded the peak rainfall. As regards the consistency in the rainfall, June and July were found to be the months of (relatively) consistent rain-

TABLE 2

Average monthly rainfall of Andhra Pradesh (1961-62 to 1990-91)

District (1)	Jun (2)	Jul (3)	Aug (4)	Sep (5)	Oct (6)	Nov (7)	Dec (8)	Jan (9)	Feb (10)	Mar (11)	Apr (12)	May (13)
Coastal Andhra region												
1 Srikakulam												
Mean (mm)	145.96	178.54	182.79	199.08	183.00	84.04	4.41	6.06	15.64	17.71	24.48	68.67
C.V. (%)	45.55	33.34	34.44	44.84	60.16	131.46	168.23	175.38	161.82	165.25	79.46	91.68
2 Visakhapatnam												
Mean (mm)	123.67	156.12	173.83	168.41	193.79	80.12	5.04	7.71	14.08	21.46	35.58	106.87
C.V. (%)	43.60	32.58	41.12	36.48	55.58	127.57	183.05	151.75	155.56	131.77	83.95	134.79
3 East Godavari												
Mean (mm)	128.67	193.33	201.17	165.29	190.00	91.33	15.75	6.88	12.83	9.63	23.92	77.63
C.V. (%)	50.44	48.08	47.70	39.82	56.67	130.76	169.47	169.21	167.70	185.19	137.19	158.36
4 West Godavari												
Mean (mm)	130.00	212.54	219.75	160.58	160.79	68.42	12.58	6.67	10.67	12.21	26.88	70.67
C.V. (%)	65.71	49.99	51.95	38.25	53.69	143.07	91.19	168.12	194.14	214.01	142.49	151.26
5 Krishna												
Mean (mm)	110.46	199.88	189.83	156.75	147.42	71.20	14.79	4.92	7.88	9.50	13.67	54.50
C.V. (%)	42.01	49.72	49.32	48.18	57.16	120.85	174.04	216.65	158.17	160.75	109.27	166.69
6 Guntur												
Mean (mm)	34.12	151.54	142.83	141.79	134.13	83.50	17.63	5.63	9.17	9.75	11.38	62.29
C.V. (%)	43.52	54.60	55.88	50.67	50.99	111.37	175.22	185.85	176.45	151.59	144.22	175.94
7 Nellore												
Mean (mm)	39.08	92.63	88.21	109.54	252.38	279.63	100.50	15.83	14.50	4.87	10.21	43.12
C.V. (%)	42.58	48.02	76.25	59.43	61.92	54.42	83.39	251.57	344.56	139.30	129.31	151.92
Rayalaseema region												
8 Kurnool												
Mean (mm)	72.29	111.58	122.83	142.38	101.08	29.75	5.79	1.50	1.63	7.00	15.33	50.25
C.V. (%)	28.59	51.72	73.80	43.84	80.51	102.11	150.78	231.78	204.35	164.56	67.87	68.15
9 Anantapur												
Mean (mm)	47.42	67.29	69.42	143.25	105.29	37.29	7.59	1.46	2.63	6.13	14.08	58.63
C.V. (%)	45.32	89.73	78.50	49.83	55.61	92.19	109.36	242.63	214.56	171.39	72.38	65.88
10 Cuddapah												
Mean (mm)	58.00	105.21	101.54	135.67	135.54	86.79	22.67	3.67	3.25	5.83	11.25	43.96
C.V. (%)	38.80	67.07	74.84	53.21	54.92	67.38	98.25	318.93	273.75	154.55	113.24	70.41
11 Chittoor												
Mean (mm)	54.13	106.04	95.83	141.42	158.00	141.38	61.25	7.04	10.25	9.21	17.58	54.83
C.V. (%)	38.43	46.34	60.27	42.99	48.68	52.99	92.19	251.41	230.48	173.28	92.10	63.60
Telangana region												
12 Hyderabad												
Mean (mm)	121.58	181.00	175.17	159.21	101.00	23.33	3.13	8.25	6.46	11.75	18.92	31.17
C.V. (%)	31.18	53.56	58.85	60.45	92.58	209.37	160.78	181.56	232.78	158.63	92.81	127.60
13 Nizamabad												
Mean (mm)	172.63	298.25	315.33	180.54	81.46	18.04	4.08	7.12	5.29	9.00	7.58	23.63
C.V. (%)	56.44	49.89	59.50	76.86	109.41	194.04	187.75	141.16	206.00	199.60	86.94	172.57
14 Medak												
Mean (mm)	139.46	237.25	228.58	169.25	82.42	19.33	2.88	5.21	5.38	7.29	16.50	29.21
C.V. (%)	38.38	60.47	51.57	59.24	91.58	178.84	175.66	192.58	219.37	178.51	99.68	123.94
15 Mehaboobnagar												
Mean (mm)	84.00	144.17	151.21	147.46	82.04	23.71	1.83	2.63	3.42	6.96	15.71	38.13
C.V. (%)	25.23	47.01	55.42	43.72	91.94	162.13	154.84	212.20	256.02	183.82	80.29	127.96

TABLE 2 *(Contd.)*

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
16	Nalagonda												
	Mean (mm)	101.92	152.00	141.21	140.12	103.21	39.00	5.83	4.83	5.75	8.00	12.63	33.88
	C.V. (%)	41.67	56.67	44.25	59.51	82.32	134.99	223.38	163.33	201.59	183.60	83.88	112.54
17	Warangal												
	Mean (mm)	151.54	272.33	229.25	152.25	96.00	25.46	9.21	8.54	9.92	10.83	11.29	36.33
	C.V. (%)	48.51	53.13	44.46	59.83	83.38	125.84	191.07	171.36	183.62	174.44	72.02	117.59
18	Khammam												
	Mean (mm)	149.54	291.75	253.50	170.63	116.08	30.83	4.13	4.83	7.79	9.75	17.42	61.79
	C.V. (%)	43.94	41.10	45.02	40.95	75.57	130.06	254.18	132.64	144.01	164.78	79.38	144.75
19	Karimnagar												
	Mean (mm)	160.46	262.83	250.38	152.17	79.54	20.88	6.92	11.25	7.63	9.29	13.92	25.17
	C.V. (%)	49.36	49.84	52.05	50.11	106.63	152.24	226.72	114.23	195.82	134.36	84.67	124.29
20	Adilabad												
	Mean (mm)	180.04	306.13	306.92	154.75	72.33	14.46	7.17	8.71	8.83	10.17	10.33	21.42
	C.V. (%)	44.93	57.08	50.87	63.46	105.78	157.15	187.05	127.89	165.97	217.04	88.73	135.40

fall in all the districts of the State. eventhough the average rainfall during these months is low.

Northeast monsoon — During this season. October was found to be peak as well as consistent rainy month in all the districts of coastal Andhra and Rayalaseema regions. The Coefficient of Variation (C.V.) ranged from 48% (Chittoor) to 80% (Kurnool). In Telangana region eventhough October is the peak rainy month (116.08 mm. Khammam). it is unstable (C.V. ranged from 75 to 106%).

Hot weather period — Highest rainfall during this season was recorded in May in all the districts of the State. However. it was associated with a high degree of instability in the districts of coastal Andhra and Telangana regions.

The results of the clusterings obtained by applying the average linkage method are presented in Table 1 and Figs. 2 (a-d). It can be observed in general that the clustering differed from season to season due to the differences in the availability of rainfall in the seasons (and also among the districts). Further. the districts classified under a cluster also need not be from the same region. These clusterings can be. therefore, considered seasonwise.

Southwest monsoon — The similarities in the pattern of rainfall among the districts as observed in the form of the distance matrix *D* have lead to classification of the districts into 5 clusters during this season. It can be observed from the distance matrix (Table 3) that in the 13th row which represents the d^2_{ij} values of Nizamabad district, no other district is as close as Adilabad (d^2_{ij} = 0.30). Hence these two districts formed a cluster.** Extending the same analogy, it can be observed from 12th row (Hyderabad) that no other districts excepting the 5 districts of coastal Andhra Pradesh (1 to 5) are relatively closer to Hyderabad [Table 3 and Fig. 2 (a)]. Needless to mention that the districts classified in a cluster for this season have a 'similar' pattern of rainfall during June to September months. This can also be verified from Table 1.

Northeast monsoon — There existed 5 clusters during this season. The 7 districts of coastal Andhra region can be seen to be classified into 2 clusters alongwith the districts of Rayalaseema region; whereas. the 6 districts of Telangana region alone formed the largest cluster. Nellore is classified as an independent district (single district cluster) due to its highly 'differential' pattern of rainfall during October to December months [Fig. 2 (b)]. Nellore recorded relatively highest rainfall during these months as compared to the other districts (Table 1).

Hot weather period — Contrary to the earlier seasons, independent behaviour of 3 districts can be observed in the clusterings of this season. Out of these, two districts are from coastal Andhra region (Srikakulam and Visakhapatnam). The largest cluster

** To avoid complexity in presenting the number of tables, the distance matrix *D* is presented only corresponding to southwest monsoon season. It is hoped that this Table 3 would serve the purpose for explaining the genesis of the clustering approach. The final outcome, however, can be studied through the dendrograms of the respective seasons.

TABLE 3

Distance matrix D — southwest monsoon

S. No.	District	SRK	VZG	EGD	WGD	KRSN	GNTR	NLR	KRNL	ANTP	CDP	CHTR	HYD	NZB	MDK	MBNR	NLG	WGL	KHM	KRMN	ADB
1	SRK	0.0	0.7	0.9	1.6	1.8	3.6	11.2	5.2	9.9	7.8	7.3	0.4	7.1	1.9	3.4	2.6	3.7	4.7	3.7	8.0
2	VZG	0.7	0.0	0.5	1.2	0.8	1.2	6.4	2.2	6.0	3.9	3.8	0.2	8.9	2.2	1.1	0.7	4.3	5.7	4.3	9.5
3	EGD	0.9	0.5	0.0	0.2	0.2	1.9	8.6	3.9	9.0	5.8	5.8	0.2	5.4	0.6	1.9	1.4	1.9	2.9	2.0	5.9
4	WGD	1.6	1.2	0.2	0.0	0.3	2.7	10.1	5.2	11.1	7.2	7.3	0.6	3.9	0.2	2.7	2.2	1.2	1.8	1.2	4.2
5	KRSN	1.8	0.8	0.2	0.3	0.0	1.2	6.9	3.1	7.9	4.6	4.7	0.2	6.3	0.9	1.3	1.0	2.2	3.3	2.5	6.6
6	GNTR	3.6	1.2	1.9	2.7	1.2	0.0	2.4	0.5	3.1	1.1	1.2	1.1	12.9	4.3	0.0	0.2	6.5	8.4	7.0	13.3
7	NLR	11.2	6.4	8.6	10.1	6.9	2.4	0.0	1.1	0.8	0.3	0.5	6.7	26.0	12.9	2.5	3.3	16.3	19.3	17.2	26.2
8	KRNL	5.2	2.2	3.9	5.2	3.1	0.5	1.1	0.0	1.1	0.3	0.2	2.7	18.0	7.4	0.4	0.9	10.4	12.8	10.9	18.6
9	ANTP	9.9	6.0	9.0	11.1	7.9	3.1	0.8	1.1	0.0	0.7	0.5	6.9	28.0	14.1	2.9	3.7	18.2	21.2	19.0	28.8
10	CDP	7.8	3.9	5.8	7.2	4.0	1.1	0.3	0.3	0.7	0.0	0.1	4.3	21.5	9.7	1.2	1.7	12.8	15.5	13.5	21.9
11	CHTR	7.3	3.8	5.8	7.3	4.7	1.2	0.5	0.2	0.5	0.1	0.0	4.2	21.7	9.8	1.2	1.8	13.1	15.6	13.9	22.3
12	HYD	0.4	0.2	0.2	0.6	0.2	1.1	6.7	2.7	6.9	4.3	4.2	0.0	7.4	1.3	1.1	0.6	2.9	4.2	3.1	7.8
13	NZB	7.1	8.9	5.4	3.9	6.3	12.9	26.0	18.0	28.0	21.5	21.7	7.4	0.0	2.5	12.9	11.9	1.8	0.9	1.3	0.3
14	MDK	1.9	2.2	0.6	0.2	0.9	4.3	12.9	7.4	14.1	9.7	9.8	1.3	2.5	0.0	4.3	3.6	0.5	0.9	0.5	2.8
15	MBNR	3.4	1.1	1.9	2.7	1.3	0.0	2.5	0.4	2.9	1.2	1.2	1.1	12.9	4.3	0.0	0.3	6.8	8.6	7.2	13.4
16	NLG	2.6	0.7	1.4	2.2	1.0	0.2	3.3	0.9	3.7	1.7	1.8	0.6	11.9	3.6	0.3	0.0	5.6	7.6	6.1	12.1
17	WGL	3.7	4.3	1.9	1.2	2.2	6.5	16.3	10.4	18.2	12.8	13.1	2.9	1.8	0.5	6.8	5.6	0.0	0.3	0.1	1.5
18	KHM	4.7	5.7	2.9	1.8	3.3	8.4	19.3	12.8	21.2	15.5	15.6	4.2	0.9	0.9	8.6	7.6	0.3	0.0	0.3	0.9
19	KRMN	3.7	4.3	2.0	1.2	2.5	7.0	17.2	10.9	19.0	13.5	13.9	3.1	1.3	0.5	7.2	6.1	0.1	0.3	0.0	1.1
20	ADB	8.0	9.5	5.9	4.2	6.6	13.3	26.2	18.6	28.8	21.9	22.3	7.8	0.3	2.8	13.4	12.1	1.5	0.9	1.1	0.0

(consisting of 7 districts) consisted of mostly the same districts of Telangana that were classified in northeast monsoon [Fig. 2 (c)]. Further, districts from all the three regions find their representation in the next largest cluster.

Overall period — When the rainfall of all the 12 months is considered, it has resulted in a different classification. The 7 districts of coastal Andhra were classified into 3 clusters, with Nellore representing a single district cluster. Similarly, the 9 districts of Telangana were grouped into two clusters each consisting of respectively 6 and 3 districts of this region [Fig. 2 (d)]. As in northeast monsoon, Nellore emerged as a single district cluster; two districts of Rayalaseema, *viz.*, Chittoor and Anantapur also exhibited an independent behaviour with regard to the annual rainfall.

It can be thus observed that there is some similarity in the clusterings of Telangana districts in all the seasons excepting the southwest monsoon. Similarly, East and West Godavari districts of coastal Andhra exhibited the same similarity in the pattern of rainfall during all the seasons considered for the study: whereas, barring the southwest monsoon, the districts of Rayalaseema region exhibited a distorted behaviour in the rainfall during the remaining seasons.

These similarities in the pattern of rainfall would help in planning suitable agricultural technologies specific for the clusters of the districts, as each cluster represents a homogeneous group. Rainfall is one of the important decision variable for agricultural planning. Information on similarities in the pattern of rainfall of a cluster of districts would help in crop planning and also in the choice of technologies such as selection of suitable crop variety (depending on the availability of rainfall), time of sowing, fertilisation and contingent planning. This concept is implemented in the agro-climatic regional planning, initiated by the planning commission.

5. Conclusion

The average linkage method of clustering has been applied to classify the 20 districts of Andhra Pradesh State on the basis of the availability of rainfall in different seasons. It was found that due to the variation in the rainfall during the different seasons, the clusterings of districts varied from season to season. In a majority of clusterings, there was a representation of districts from all the three regions of Andhra Pradesh. Information on seasonwise clusterings would be beneficial for planning crop improvement measures suitable for a cluster.

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