551.585 : 551.577 (548.4)

RAINFALL BASED CLASSIFICATION OF ANDHRA PRADESH THROUGH THE ESTIMATES OF ASSURED RAINFALL

1. Rainfall based classifications are generally based on similarities in the mean values of rainfall variables (White and Perry 1989, Briggs and Lemin Jr 1992 and Kulkarni and Reddy 1994). Rainfall recorded over a period of time generally exhibits considerable year-to-year variations and is therefore inconsistent (unstable). Hence the choice of mean rainfall would be appropriate only for summarizing the characteristics, but in appropriate for agricultural planning. The most suitable approach would be to obtain a classification based on "assured" availability of rainfall. Here, an attempt has been made to obtain a classification of the districts of Andhra Pradesh State, which accounts for the "assured" availability of rainfall.

2. Suppose there are 'm' regions for which 'n' years of monthly rainfall data are available. Let $X(i)$ be the observation vector corresponding to the i-th region (i = 1, …, m). Let $X(i)$ represents the estimates of assured rainfall of 'k' months of the season. Now, based on $X(i)$, the 'm' regions are to be classified into homogeneous groups, as described below :

Estimates of Assured Rainfall - The assured rainfall, which is also referred as 'Dependable Precipitation' (DP) in the context of measuring the Moisture Availability Index (MAI), is the largest possible rainfall that can occur in a period (week/month/season) at a given probability. The assured rainfall $X(p)$ at p-th level of probability can be expressed with a probabilistic expression :

$$P\left[X \geq X(p)\right] = \int_{X(p)}^{\infty} f(x)\,\mathrm{d}x = p\,,$$

or, alternatively,

$$P\left[X \leq X(p)\right] = 1 - P\left[X \geq X(p)\right] = (1-p) = q$$

i.e., $X(p)$ is the $(1 - p)$th percentile of the frequency distribution $f(x)$ of the rainfall variable X.

TABLE 1

Characteristics of Andhra Pradesh rainfall (mm) 1961-95

District	Jun	Jul	Aug	Sep	Oct	District	Jun	Jul	Aug	Sep	Oct
(A) Coastal Andhra Region											
1. *Srikakulam (SRK)*						11. *Chittoor (CHTR)*					
A.M.	140.09	182.60	193.89	194.86	194.83	AM	60.54	105.89	102.00	137.94	161.51
CV (%)	44.00	31.32	36.38	39.47	54.92	CV (%)	49.50	43.90	52.39	39.97	45.66
Estimate	93.00	140.00	145.00	148.00	99.00	Estimate	43.00	71.00	54.00	103.00	108.00
2. *Viskhapatanam (VZG)*						**(c) Telangana Region**					
A.M.	119.91	161.77	163.94	173.86	210.20	12. Hyderabad (HYD)					
CV (%)	44.13	31.10	40.77	33.06	53.92	AM	119.69	179.83	178.17	166.80	105.31
Estimate	86.00	128.00	108.00	130.00	94.00	CV (%)	32.04	47.94	50.31	62.57	87.13
3. *East Godavari (EGD)*						Estimate	88.00	109.00	125.00	87.00	37.00
AM	125.89	201.94	192.77	174.77	203.29	13. *Nizamabad (NZB)*					
CV (%)	49.47	40.76	42.61	41.62	52.96	AM	164.69	294.34	292.91	171.00	93.46
Estimate	72.00	136.00	150.00	119.00	118.00	CV (%)	53.56	44.18	56.72	71.72	111.18
4. *West Godavari (WGD)*						Estimate	107.00	222.00	178.00	90.00	18.00
AM	128.51	222.34	218.37	172.63	175.23	14. *Medak (MDK)*					
CV (%)	63.73	42.28	47.38	42.34	50.32	AM	136.03	231.29	219.40	161.60	96.26
Estimate	74.00	162.00	157.00	116.00	100.00	CV (%)	36.11	53.17	47.11	59.77	83.86
5. *Krishna (KRSN)*						Estimate	91.00	152.00	152.00	83.00	25.00
AM	110.74	196.86	193.11	167.31	158.91	15. *Mehaboobnagar (MBNR)*					
CV (%)	42.67	45.02	42.91	51.36	55.75	AM	90.83	155.91	158.03	143.03	93.00
Estimate	74.00	127.00	155.00	98.00	73.00	CV (%)	47.98	42.84	52.09	56.70	79.30
6. *Guntur (GNTR)*						Estimate	61.00	105.00	96.00	90.00	31.00
AM	86.51	148.54	143.83	147.60	145.20	16. *Nalgonda (NLG)*					
CV (%)	44.97	48.97	49.36	54.88	52.74	AM	100.03	146.89	138.20	146.11	115.63
Estimate	62.00	96.00	90.00	85.00	76.00	CV (%)	45.95	52.41	39.32	61.65	74.63
7. *Nellore (NLR)*						Estimate	58.00	82.00	108.00	84.00	56.00
AM	46.63	97.11	96.09	110.46	240.71	17. *Warangal (WGL)*					
CV (%)	82.93	41.84	62.35	56.43	58.11	AM	143.97	274.34	227.37	157.43	104.49
Estimate	26.00	68.00	51.00	68.00	111.00	CV (%)	45.66	45.39	39.74	56.42	79.41
(B) Rayalseema Region						Estimate	107.00	191.00	149.00	86.00	28.00
8. *Kurnool (KRNL)*						18. *Khammam (KHM)*					
AM	74.23	113.86	119.43	133.69	104.57	AM	148.97	292.31	254.03	176.74	119.69
CV (%)	45.61	45.05	66.01	53.29	73.57	CV (%)	41.25	37.99	41.15	38.42	67.00
Estimate	52.00	65.00	62.00	74.00	51.00	Estimate	110.00	241.00	181.00	131.00	47.00
9. *Anatapur (ATP)*						19. *Karimnagar (KRMN)*					
AM	52.40	65.69	79.14	130.09	110.14	AM	146.80	254.11	232.23	153.06	89.43
CV (%)	48.50	80.79	73.69	53.04	49.22	CV (%)	48.50	45.47	48.67	52.85	91.46
Estimate	33.00	30.00	28.00	78.00	60.00	Estimate	95.00	191.00	163.00	92.00	22.00
10. *Cuddapah (CDP)*						20. *Adilabad (ADB)*					
AM	64.46	108.14	101.29	120.54	130.49	AM	175.14	310.80	305.37	154.86	80.74
CV (%)	60.04	57.09	63.00	57.72	52.18	CV (%)	40.91	48.40	47.69	59.27	111.89
Estimate	33.00	64.00	62.00	62.00	77.00	Estimate	122.00	221.00	209.00	88.00	21.00

It is thus obvious that as the level of q increases, the magnitude of $X(p)$ also increases. However, the values at the higher percentiles are less frequent and therefore not "likely" to represent the assured rainfall. Hence, the choice of $X(p)$ is corresponding to the lower percentiles. In this context, Viramani (1975) and Hargreaves (1975) advocated $p = 0.75$ as the acceptable level for estimating the rainfall on monthly basis; whereas, Biswas and Sarker (1978) and Sarker, *et al*., (1982) considered 50 per cent probabilistic rainfall as the dependable precipitation for

TABLE 2

Rainfall based classification of Andhra Pradesh State

Cluster	District	Jun	Jul	Aug	Sep	Oct	District	Jun	Jul	Aug	Sep	Oct
		Classification with Mean rainfall						Classification with Dependable rainfall estimate				
1.	SRK,VZG,EGD, WGD,KRSN	111 - 140	162 - 222	164 - 218	167 - 195	159 - 210	SRK,VZG,EGD, WGD,KRSN	72 - 93	127 - 162	108 - 157	98 - 148	73 - 118
2.	GNTR,HYD, MBNR,NLG	87 - 119	147 - 156	138 - 158	143 - 148	93 - 145	GNTR,HYD MBNR,NLG	58 - 88	82 - 109	90 - 125	84 - 90	31 - 76
3.	KRNL,ATP, CDP,CHTR	52 - 74	66 - 114	79 - 119	121 - 138	105 - 162	NLR,KRNL,ATP, CDP,CHTR	26 - 52	30 - 71	28 - 62	62 - 103	51 - 111
4.	NZB,MDK,WGL, KHM,KRMN,ADB	136 - 175	231 - 311	219 - 305	153 - 177	81 - 120	NZB,KHM, ADB	107 - 122	221 - 241	178 - 209	88 - 131	18 - 47
5.	NLR	47	97	96	110	241	MDK,WGL, KRMN	91 - 107	152 - 191	149 - 163	82 - 92	22 - 28

(Rainfall Ranges in "mm")

rainfall measured on weekly basis. Since the present study involves monthly rainfall data, the dependable rainfall $X(p)$ was estimated at $p = 0.75$.

The estimate of assured rainfall $X(p)$ can be conveniently obtained from the percentiles of the distribution $f(x)$. $X(p)$ is the $(1 - p)$th percentile of $f(x)$. The percentiles of the rainfall distribution are generally obtained by fitting statistical distributions to the yearly rainfall data. These distributions are either Gamma or Normal distribution (Hills and Morgan 1981). A less restrictive approach, which do not assume any statistical distribution, was proposed by Davy, *et al.,* (1976). The approach involves empirically determining the percentiles from the array of rainfall data as follows : The 'n' years of rainfall data (corresponding to a month) can be arranged in the ascending order of magnitude. Now, if $q = (1 - p)$ is any chosen level of proportion, the $(100 \times q)$th percentile which is the estimate $X(p)$, is represented by the $(n \times q)$th value of the array.

Classification of regions - The region-wise rainfall data on the observation vector X_i (i = 1, …, m) which represents the vector of estimates of assured rainfall (of the rainfall months) obtained at $p = 0.75$ can be subjected to Cluster Analysis. Among the various methods of clustering, those based on Hierarchical approach and in particular, the Ward's Minimum Variance method can be applied due to its several advantages over the other approaches (Everitt 1974).

The approach outlined above was applied for obtaining the rainfall-based classification of Andhra Pradesh state. Classification was obtained by using 35 years of monthly rainfall data covering the years 1960-61 to 1994-95. For the purpose of classification, only 20 districts out of the 23 districts of the State were considered, due to the non-availability of complete data on the three recently formed districts of Vizianagaram, Prakasam and Ranga Reddy.

Clustering of the districts was obtained by taking the 5 rainfall variables in the observation vector. These variables were the monthly rainfall of June to October. Classification was obtained on the basis of the two criterions : the mean rainfall and the estimates of assured rainfall. Statistical Abstracts of Andhra Pradesh State were the source of data.

3. The rainfall characteristics of the districts are presented in Table 1. In general, it can be observed that July and August are "peak" as well as consistent rainfall months. The exceptions are the districts of Anantapur, followed by Cuddapah; while Kurnool and Nellore districts recorded inconsistent rainfall only during August (C.V. : 66 per cent and 62 per cent, respectively). The mean rainfall of these "peak" rainy months ranged from 105 mm (Chittoor) to 310 mm (Adilabad) in case of July month; while in August, the range is from 138 mm (Nalagonda) to 305 mm (Adilabad). Coastal Andhra region received mostly consistent rainfall in Southwest monsoon season (with the exception of West Godavari and Nellore districts); while inconsistent rainfall respectively during August and September is the characteristic of the districts of Rayalseema and Telangana regions (Table 1). On the whole, these characteristics indicate the inconsistent nature of rainfall and also the in-appropriate choice of the mean values for

agricultural planning. The most suitable choice would be the estimates of dependable, *i.e.,* the assured rainfall which is generally obtained at 0.75 level of probability.

The estimates of assured rainfall are obviously less than the corresponding mean values. If the distribution of the rainfall variable were symmetric, the mean values would represent the median or the 50^{th} percentile of the data; while the estimate of assured rainfall (or, the dependable rainfall) would represent the 25 percentile of the data. However, the frequency of occurrence of rainfall less than this estimate is sufficiently greater than with the mean values. *i.e.,* at least a "minimum" possible rainfall represented by the estimate is "assured" with a probability of 0.75.

In the light of these limitations of the mean values, consider the results of cluster analysis, which are presented in Table 2. Considering the spatial variation in the rainfall, the districts were classified in 5 clusters.

The clusters obtained on the basis of mean values of the rainfall variables represented 5 different levels: for instance, the districts of Cluster 4 exhibited relatively maximum level of the means for the rainfall of June to September. This cluster was formed with 6 districts all of which belong to the Telangana region. This is followed by the pattern of Cluster 1 formed with 5 districts which belong to the coastal Andhra region; whereas, the Cluster 5 formed with the single district of Nellore represented a relatively minimum level for the mean rainfall of these months, while a relatively maximum level for the mean rainfall of October month (240 mm, Table 1.).

The classification based on the estimates of assured rainfall led to different clusters. However, the first two clusters were identically similar to those of the mean values. The clusters also represented the different levels for the 'availability' of rainfall in the districts. It can be observed that the districts of Cluster 4 have relatively maximum level for the availability of rainfall (estimates of assured rainfall) in June to September; while a relatively low level in October. The three districts of Telangana region, *viz*. Nizamabad, Adilabad and Khammam, which formed this cluster, were also classified along with other districts in the same cluster when the criterion of classification was the mean values. However, the level of October rainfall represented by the estimates of assured rainfall was considerably lower than the mean values. The level of the estimate ranged from 18 mm (Nizamabad) to 47 mm (Adilabad) as against the corresponding mean values of 93.46 mm (Nizamabad) and 80.74 mm (Adilabad). The low level of the estimate can be attributed to the highly inconsistent occurrence of rainfall with c.v.s for both these districts of the order of 111 percent.

The mean values of the rainfall variables are always at a higher level and also inconsistent. Hence, it is obvious that for agricultural planning, the classification based on the mean values would be misleading and may lead to heavy crop losses. On the contrary, the level of rainfall represented with the estimates of assured rainfall in the 5 clusters can be effectively utilized for strategic planning.

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B. S. KULKARNI
G. KRISHNA KANTH
Dept. of Statistics & Maths, College of Agriculture, A.N.G.R. Agricultural University, Hyderabad, India
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