Objective Regionalisation of Tamil Nadu, a Southern State of India based on Principal Component Analysis

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ABSTRACT

The daily rainfall of 29 districts of Tamil Nadu during northeast monsoon is used for principal component analysis. Out of 29 districts, 22 districts are grouped into five homogenous Sub-regions which are having stronger relationship with five Varimax rotated principal components and the 7 districts are found with weak / moderate relations to any of the Principal components. Tamil Nadu is regionalised in to five Sub-regions based on strong relationship with first 5 PCs. Sub-region 1 comprises of districts Cuddalore, Perambalur, Pudukottai, Thanjavur, Thiruvarur and Nagapattinam. The Interior districts Madurai, Sivaganga, Virudhunagar and Dindugul make sub-region II. The districts Dharmapuri, Salem, Namakkal, Karur, Erode, Nilgiris and Coimbatore make Sub-region III and the districts Chennai, Kanchipuram, Vellore and Thiruvallur form Sub-region IV. The group of districts Tirunelveli, Thoothukudi and Kanyakumari make Sub-region V.

Keywords: *Principal component analysis, sub-regions, northeast monsoon, climate variables.*

1. Introduction

Tamil Nadu is one of the southernmost states of India The proximity of sea influences the climate of eastern and southern part of Tamil Nadu whereas hilly orography and distance from the sea play an important role over rest of the State. The topography and proximity to sea influences the rainfall distribution of Tamil Nadu and the state provides an interesting area for studies of spatial variability of rainfall. As per convention followed by India Meteorological Department at Chennai, Tamil Nadu is divided into four sub regions mainly based on their proximity to coast and their geographical location for the purpose of regional level forecasting of weather over Tamil Nadu (Fig.1). They are namely, (1) North Coastal Tamil Nadu (NCTN), (2) South Coastal Tamil Nadu (SCTN), (3) North Interior Tamil Nadu (NITN) and (4) South Interior Tamil Nadu (SITN). It may be noted that objective regionalisation concept is not a factor for the classification of the administrative districts.

Objective regionalisation based on different climate variables like temperature and rainfall is the basis for dividing the large areas into many sub regions. This regionalisation can be obtained by using different methods, ranging from elementary linkage analysis to more complex multivariate statistical techniques like factor analysis, cluster analysis, corresponding analysis, etc. Sumner and Bonell (1990) used linkage analysis regionalisation of Wales based on the daily rainfall data. Barring (1987) applied common factor analysis for the regionalisation of daily rainfall of Kenya. White et al (1991) made use of cluster analysis and different rotation algorithms to monthly Pennsylvanian precipitation data while Bonell and Sumner (1992) used cluster analysis and obliquely rotated Principal Component Analysis (PCA) for the daily precipitation in Wales. Fovell and Fovell (1993) identified the climatic zones and sub zones of the conterminous United States from monthly temperatures and precipitation after clustering the orthogonally rotated principal components. Also objective regionalisation was done by Sumner et al (1993) for Mallorea, Periago et al (1991) for Catalonia and Romero et al (1999) for whole of Spain. Therefore, arriving an objective regional division shall be more meaningful and can be explained with reasoning. Further such objective analysis will facilitate forecasting in a more meaningful way.

Identifying basic rainfall regions of Tamil Nadu objectively, therefore, may explain the sub regional characteristics of the distribution. In other words, the identification of the 29 districts of Tamil Nadu into fewer objective rainfall regions can serve for practical administrative purposes. This type of regionalisation has potential use in providing a regional short, medium and long range forecasting of rainfall during NEM season.

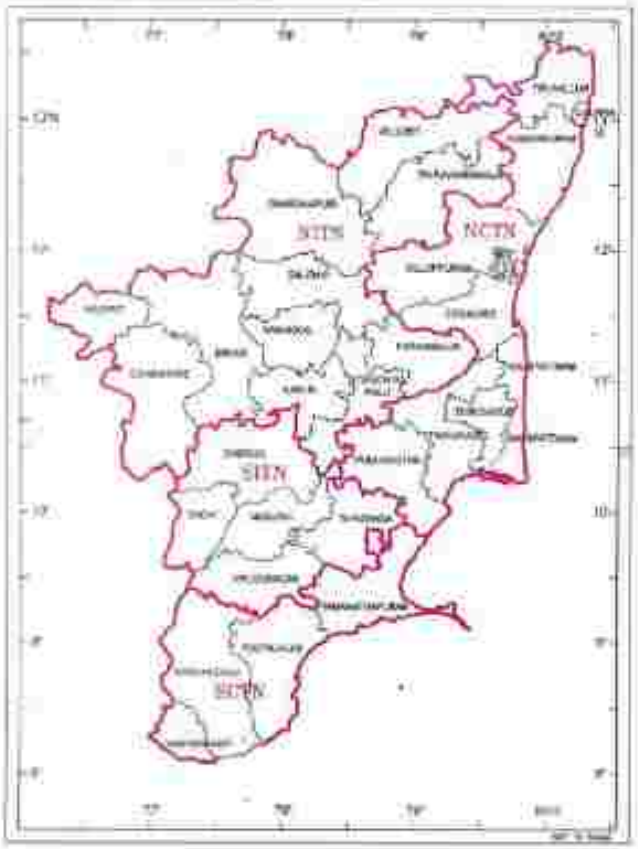


Fig.1 29 districts and four sub-regions of Tamil Nadu.

2. Data and Methodology

The daily rainfall data of 173 rain gauge stations of Tamil Nadu during the main rainy season namely northeast monsoon season (1st October to 31st December) for the period from 1965 to 1996 is used. The rain gauge stations are spatially well distributed in the state and there is no spatial bias in the data set. Based on this data, the daily rainfall data of the 29 districts of Tamil Nadu during northeast monsoon season for the period of 31 years (1965 to 1996) is constructed. The daily rainfall series is a complete time series. Here S- mode Principal component analysis (PCA) is carried out taking 29 districts as variables and 2852 days rainfall as cases to provide an objective pluviometric regionalisation of Tamil Nadu.

Since the casual mechanisms of precipitation are fuzzy and overlapping, the regionalisation based on unrotated PCs will have overlapping areas. For this reason, assuming the rotation can produce simple structures (as in Gong and Richman, 1995), rotation of PCs has been attempted. The rotation of components wants to simplify the interpretation of the derived variables and to optimise by a criterion to obtain a 'simple structure'. If the division of a region into fairly homogeneous areas is required, the rotated PCs will almost inevitably do it better than unrotated PCs (Jolliffe, 1987). Since the loadings of various PCs depend upon the number of PCs retained for rotation, several criteria based on dominant variance rule are suggested by various authors for deciding how many PCs to be retained.

Kaiser criterion (Kaiser, 1958), Scree test (Cattle, 1996) & Log-Eigen value (LEV) diagram (Craddock et al, 1969), Preisendorfer's rule 'N' are generally used as methods to decide the number PCs to be retained for rotation. Kaiser criterion says that the factors with Eigen values having greater than one are to be retained for rotation. Figure 2(a) is the Scree plot and 2(b) is LEV diagram. The goal here is to identify the break in slope or a cut off in the difference between successive PCs in the plot. The method of Preisendorfer's rule N (Preisendorfer et al (1981), Wilks (1995)) identifies the largest number of principal components to be involved on the basis of resampling tests involving the distribution of Eigen values of randomly generated dispersion matrices. The first method suggests 5 PCs for rotation but other three methods suggest 4 PCs for rotation. Here in this study, the first 5 PCs are retained for rotation as per Kaiser's criterion. Generally Varimax (orthogonal) (Richman, 1986, 1987), Quartimax (orthogonal), Equamax (orthogonal) and Oblimin (oblique) (Richman, 1981) rotation methods are used for rotation of PCs. Here in this study, Varimax rotation IS used to find out most interpretable simple structure of PC loadings.

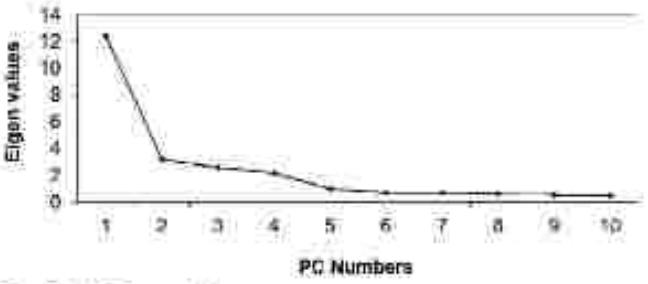


Fig.2(a) Scree diagram.

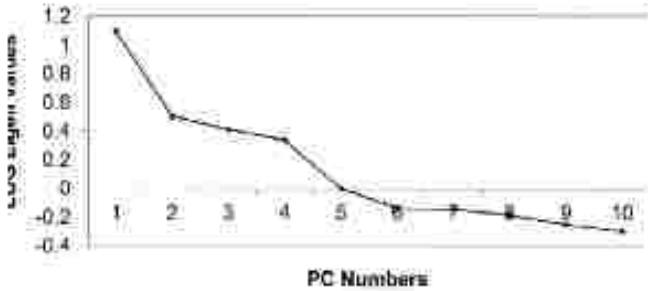


Fig.2(b) Log- Eigen value (LEV) diagram.

3. Results and Discussion

3.1 Variance explained by Principal Components

Table 1 shows the Eigen values and the corresponding variance explained by each PC with the cumulative percentage of total variance. The component loadings are the correlation coefficients between the variables and components analogous to Pearson's correlation coefficient 'r'. The squared component loadings are the percentage of variance in that variable explained by the component. To get the percentage of variance in all the variables accounted for by each component, add the sum of the squared factor loadings for that component and divide by the number of variables. Here the first 10 principal components are sufficient for explaining 85% of total variance while first 14 and 20 principal components are needed to explain 90% and 95% of total variances respectively. The first five PCs explained about 73% of total variance. In this study first five components are chosen for interpretation and further analysis, as it is often customary to restrict the choice of Eigen values higher than or equal to 1.0 only.

TABLE 1

Variance and cumulative variance explained by first 10 PCs based on 2852X29 matrix.

PC Numbers	Eigen value	Cumulative Eigen value	Variance (%)	Cumulative % of Total variance.
01	12.43	12.43	42.88	42.88
02	3.21	14.24	11.07	53.95
03	2.59	18.23	8.93	62.95
04	2.17	20.40	7.51	70.39
05	1.00	21.40	3.46	73.85
06	0.73	22.13	2.52	76.36
07	0.72	22.85	2.47	78.83
08	0.65	23.50	2.26	81.09
09	0.56	24.06	1.94	83.03
10	0.50	24.56	1.73	84.77

Fig.3a

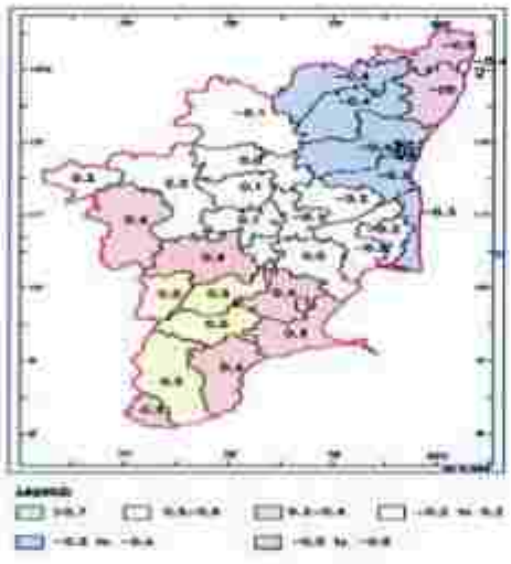
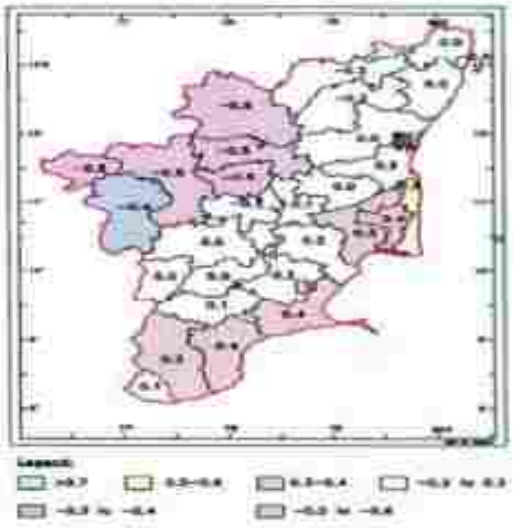
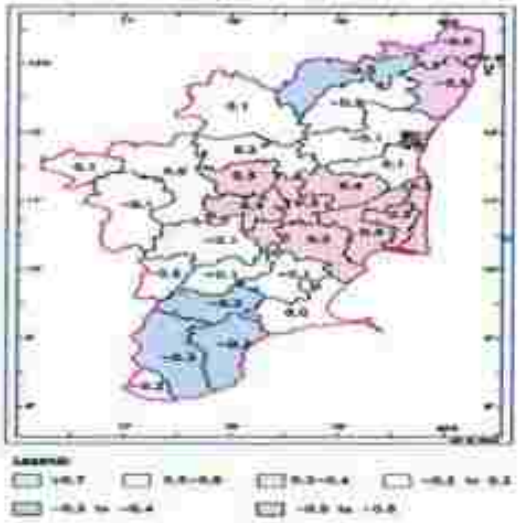


Fig.3b

(c)



(d)



(e)

Fig 3 Loadings of unrotated Principal Components (a) PC-I (b) PC-II (b)PC-III (d) PC-IV (e) PC-V.

3.2 Unrotated Principal Components.

The factor loadings of first 5 PCs are shown in Fig.3. The raw or unrotated component I (variance explained 43%) has positive loadings in all districts. This means that all districts are positively correlated with PC I. This PC indicates that first source of variance in the data is associated with the overall magnitude of rainfall events in the region as a whole. In the table, factor loadings greater than 0.7 are found in central coastal districts along with Dindugul and in some north interior districts. PC II (variance explained 11%) has positive loadings of more than 0.3 in south TN and negative loading of less than -0.3 in north coastal and neighbouring north interior districts. PC III (variance explained about 9%) has positive loadings (more than 0.3) in central coastal districts and in south coastal districts. Negative loadings (less than -0.3) are found over northwest Tamil Nadu. PC IV (variance explained is about 8%) has positive loadings of more than 0.3 in Cauvary basin region and adjoining districts while northeast Tamil Nadu have negative loading of less than -0.3. PC V (variance explained is about 3.5%) has positive loading of more than 0.3 in southern tip of Tamil Nadu while Madurai have negative loadings less than -0.3.

3.3 Varimax rotated Principal Components

A Varimax solution yields results, which make it as easy as possible to identify each variable with a single component. This is the most common rotation option. Varimax rotation is done keeping the first 5 Principal components for rotation and the factor loadings of the five rotated PCs are calculated. The coefficients of determination expressed in percentage are shown in Fig. 4(a - e). The component loadings of Varimax rotation are given in Table 2.

From the Fig.4, it is seen that the central coastal districts of Tanjavur, Tiruvarur, Nagapattinum, Pudukottai, Cuddalore and the neighbouring district Perambalur are strongly related to PC I. The districts Tiruchirapalli and Villupuram are moderately related and Karur & Ramanathapuram are weakly related to PC I. The other districts are having insignificant relationship with PC I. It can be seen from the figure 4 that the four south interior districts namely Madurai, Sivaganga, Virudhunagar and Dindugul are having strong relationship with PC II. The districts Ramanathapuram and Theni are moderately related to PC II and the districts Coimbatore, Toothugudi, Tirunelveli,

Karur and Pudukottai are weakly related to PC II. It can be inferred from figure 4 that the north interior districts Salem, Erode, Namakkal, Dharmapuri and hilly district Nilgiris are having strong relationship with PC III. The districts Karur and Coimbatore are moderately related while the districts Thiruvannamalai, Vellore, Perambalur, Dindugul and Tiruchirapalli are weakly related to PC III.

It is seen from Fig.4 that the north coastal districts namely Tiruvallur, Kanchipuram and Chennai and the neighbouring interior district Vellore are having strong relationship with PC IV. The districts Tiruvannamalai & Villupuram are moderately related to PC IV. The districts Dharmapuri and Cuddalore are weakly related to PC IV. From the Fig.4, it can be inferred that the south coastal districts namely Tirunelveli, Kanyakumari & Toothugudi are strongly related while the district Ramanathapuram is weakly related to PC V. In other words, the districts Chennai, Kanchipuram, Tiruvallur are strongly related to PC IV, the districts Tanjavur, Tiruvarur, Nagapattinum are having strong relation with PC I, the districts Namakkal, Salem, Erode & Nilgiris are strongly related to PC III, the district Kanyakumari is strongly related to PC V and the districts Madural, Sivaganga

TABLE 2
Loadings of Varimax rotated Principal Components

	PC I	PC II	PC III	PC IV	PC V
CHN	0.12	0.11	0.03	0.85	0.13
KNJ	0.25	0.13	0.10	0.87	0.07
TVL	0.18	0.10	0.10	0.89	0.11
CDL	0.73	0.12	0.21	0.34	0.13
VLP	0.54	0.09	0.28	0.61	0.05
TNJ	0.88	0.18	0.20	0.22	0.11
TRR	0.88	0.15	0.08	0.20	0.13
NGP	0.84	0.06	0.01	0.26	0.14
PDU	0.74	0.41	0.26	0.12	0.10
TVM	0.31	0.12	0.46	0.80	0.01
VLR	0.22	0.09	0.37	0.76	0.01
DRM	0.18	0.04	0.75	0.32	-0.02
NMK	0.30	0.16	0.79	0.11	0.01
SLM	0.29	0.11	0.82	0.23	0.04
CMB	0.04	0.41	0.61	0.10	0.20
ERD	0.14	0.29	0.75	0.08	0.09
NLG	0.04	0.18	0.71	0.14	0.22
KRU	0.40	0.53	0.63	0.07	0.01
PRM	0.71	0.16	0.39	0.25	0.05
TKP	0.69	0.12	0.32	0.08	0.03
RMD	0.45	0.58	0.01	0.04	0.77
TNL	0.15	0.86	0.07	0.07	0.80
TTK	0.17	0.79	0.00	0.08	0.71
KYK	0.11	0.10	0.19	0.12	0.79
MDR	0.17	0.79	0.27	0.11	0.07
THN	0.03	0.68	0.25	0.09	0.20
SVG	0.29	0.74	0.14	0.09	0.15
VRD	0.05	0.77	0.12	0.13	0.23
DND	0.29	0.70	0.48	0.15	0.12

More than 0.7 | 0.61 - 0.70 | 0.51 - 0.60

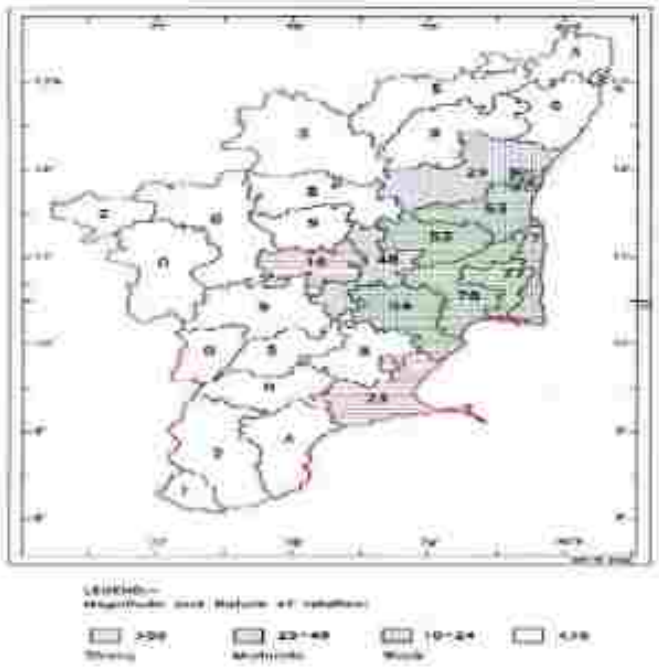


Fig.4a

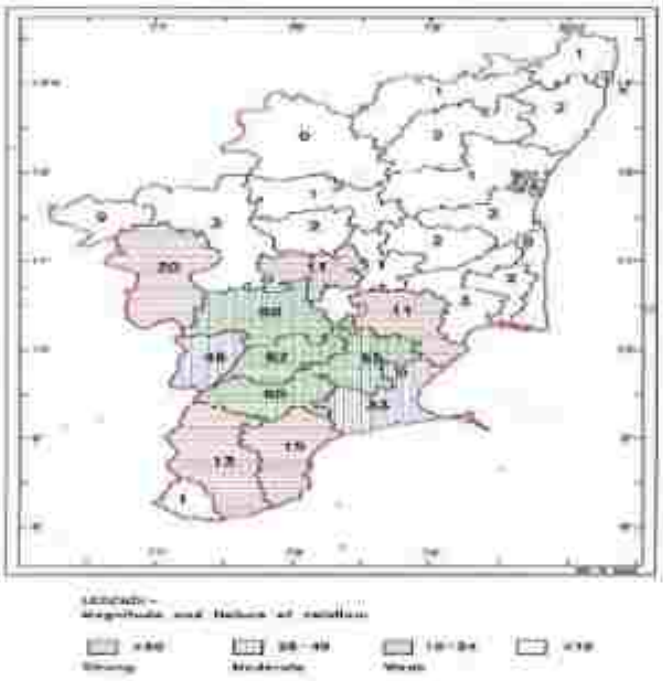


Fig.4b

& Virudhunagar are strongly related to PC II. The district Theni is moderately related to PC IV. The district Cuddalore is having a strong relationship with PC I and is having a weak relationship with PC IV.

The district Villupuram is moderately related to PC I & PC IV. The Pudukottai district is having a strong relationship with PC I and is having a weak

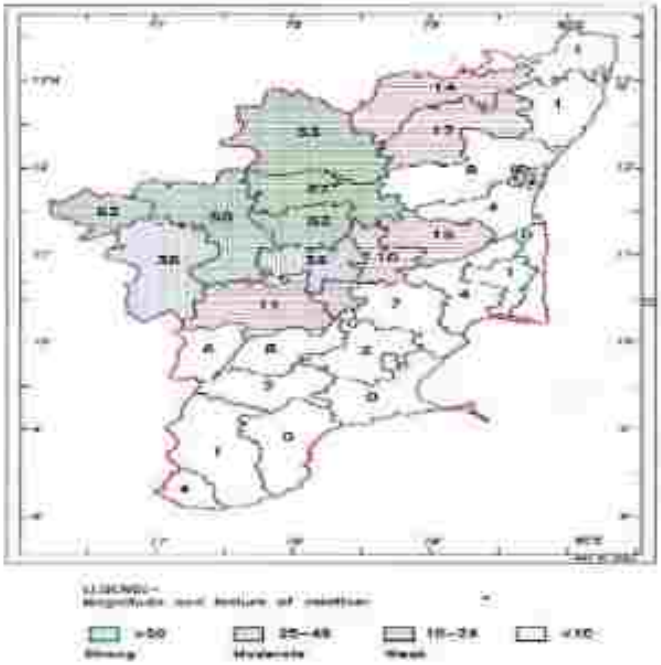


Fig.4c

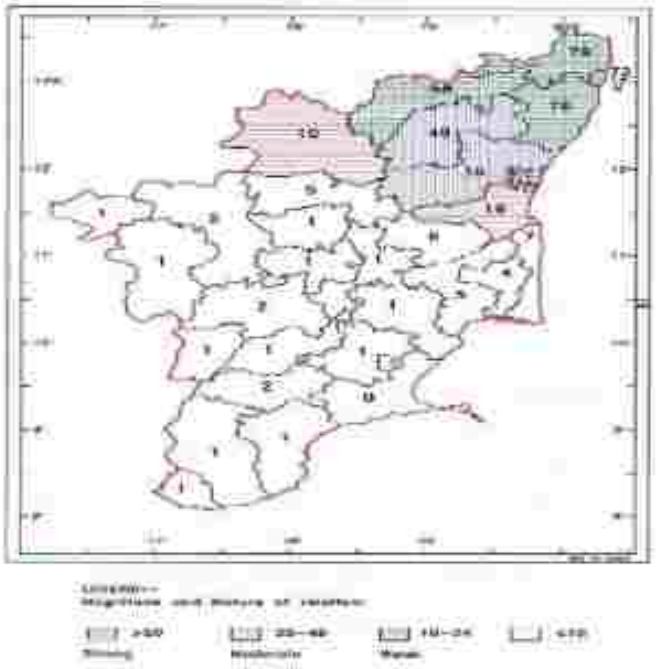


Fig.4d

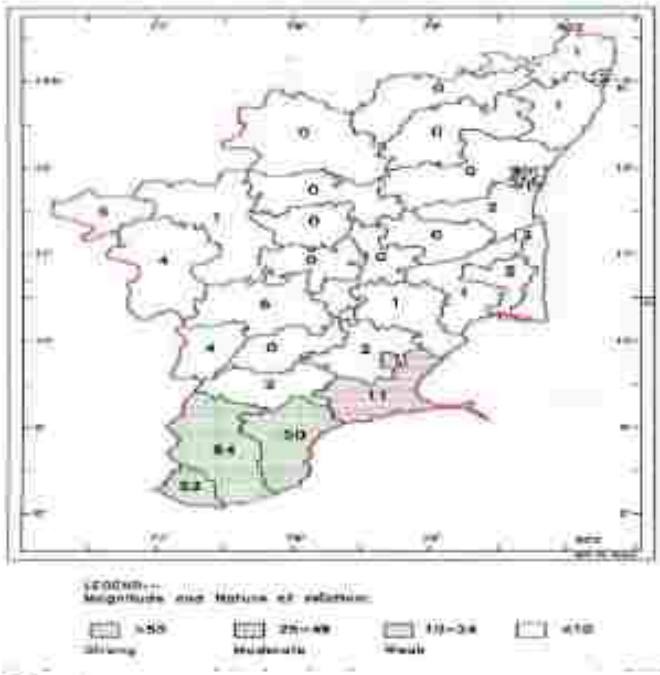


Fig.4e

Fig.4Loadings of Varimax rotated Principal components (a) PC-I (b) PC-II (c) PC-III (d) PC-IV (e) PC-V

relation with PC IV. The Tiruvannamalai district is having moderate relationship with PC IV and weak relationship with PC III while the Vellore district is having strong relationship with PC IV and a weak relationship with PC III. The Dharmapuri district is having a strong relation with PC III and a weak relation with PC IV. The Coimbatore district is having a moderate relation with PC III and a weak relation with PC II. The district Perambalur is strongly related to PC I and weakly related to PC III while Tiruchirapalli is moderately related to PC I and weakly related to PC III. The districts Tirunelveli & Toothugudi are strongly related to PC IV and weakly related to PC II. The Dindugul district is strongly related to PC II and weakly related to PC III. The Ramanathapuram district is having a moderate relation with PC II and weak relation with PC I and PC V while the Karur district is having moderate relation with PC III and weak relation with PC I and PC II. By Varimax rotation it is found that the districts Villupuram, Tiruvannamalai, Tiruchirapalli, Ramanathapuram, Coimbatore, Karur and Theni (table 3) do not have strong relations with any of the PCs. These districts are unclassified districts. They may be grouped in to a region called a fragmented rainfall region.

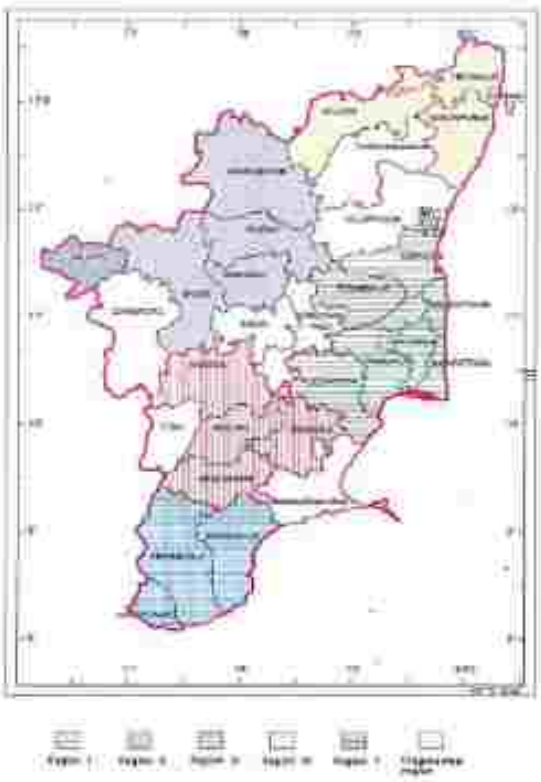


Fig.5 Five homogeneous sub-regions and fragmented region of Tamil Nadu

4. Regionalisation of NEMR

Since Varimax rotation is better to interpret the 22 districts into group of 5 regions, the results of Varimax rotation is used for regionalisation of Tamil Nadu. Based on the strong relationship of the districts with five principal components, Tamil Nadu is split into five homogeneous sub regions (Fig.5). However it is found that some of the districts are found with the high loading in factor 6 but they are spatially non contiguous. Table 3 and 4 gives the mean, SD, minimum and maximum rainfall in the month of October, November, December and Northeast monsoon season.

4.1 Sub-region I : Central coastal region

The region I comprises of Cuddalore, Tanjavur, Tiruvarur, Nagapattinum, Pudukottai and Perambalur districts. Except Perambalur all the districts are located over Central coastal Tamil Nadu. Hence this region may be called as 'Central Coastal region or Cauvary delta basin'. This region covers an area of 20,615 sq. km. There are 34 rain gauges out of 173 rain gauge stations in this region and the average height of the rain gauges is 55m amsl. This region receives a mean rainfall of 201.1 mm, 259.7 mm, 157mm and 613.5mm with standard

TABLE 3

Mean, SD, minimum and maximum rainfall of 5 regions in the month of October and November.

	October				November			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Reg. 1	201.1	96.2	46.2	587.7	259.7	148.8	28.1	856.5
Reg. 2	192.8	69.3	64.0	433.2	162.3	87.3	10.4	490.8
Reg. 3	170.7	68.7	41.2	381.8	107.3	68.0	5.2	271.0
Reg. 4	207.5	110.2	10.7	566.9	228.7	136.7	4.6	545.1
Reg. 5	179.4	76.5	33.0	398.7	200.9	95.8	29.7	493.4

TABLE 4

Mean, SD, minimum and maximum rainfall of 5 regions in the month of December and during NEMR

	December				NEMR			
	Mean	SD	Min	Max	Mean	SD	Min	Max
Reg. 1	157.0	130.7	0.3	664.8	613.5	210.0	172.0	1149.8
Reg. 2	67.8	57.9	0.2	232.7	423.2	121.2	178.2	734.4
Reg. 3	39.1	41.0	0.0	225.4	316.7	108.0	84.4	616.6
Reg. 4	97.6	109.0	0.0	569.8	533.1	200.5	106.2	1212.2
Reg. 5	89.8	76.2	0.4	379.7	469.7	154.5	157.8	931.8

deviation of 96.2mm, 148.8mm, 130.7mm and 210.0mm in the month of October, November, December and NEM season respectively. This region receives a minimum rainfall of 46.2mm and a maximum of 587.7mm, a minimum of 28.1mm and a maximum of 856.5, a minimum of 0.3mm and a maximum of 664.8 mm in the month of October, November and December respectively. During NEM season, it receives a minimum total rainfall of 172 mm and a maximum total rainfall of 1150 mm during NEM season.

4.2 Sub-region II : South interior region

The districts Madurai, Sivaganga, Virudhunagar and Dindugul constitute the region II. These districts are south interior districts and this region may be called as 'south interior region'. This region covers an area of 18,108 sq. km. There are 23 rain gauges in the region and the average height of the rain gauges is 244 m amsl. This region receives a mean rainfall of 192.8 mm, 162.3 mm, 67.8 and 423.2mm with standard deviation of 69.3mm, 87.3mm, 57.9mm and 121.2 mm in the month of October, November, December and NEMS respectively. This region receives a minimum rainfall of 64.0mm and a maximum of 433.2mm, a minimum of 10.4mm and a maximum of 490.8, a minimum of 0.2 mm and a maximum of 232.7 mm in the month of October, November and December respectively. During NEMS, it receives a minimum total rainfall of 178.2m and a maximum total rainfall of 734.4 mm during NEMS

4.3 Sub-region III : North interior or Northwest region

The districts Dharmapuri, Namakkal, Salem, Erode and Nilgiris form the region III. The districts are located over north interior Tamil Nadu and this region may be called as 'north interior region'. This region covers an area of 29029 sq. km. There are 36 rain gauges located in the region and the average height of the rain gauges is 555 m amsl. This region receives a mean rainfall of 170.7 mm, 107.3 mm, 39.1 and 316.7mm with standard deviation of 68.7mm, 68.0mm, 41.0mm and 108.0 mm in the month of October, November, December and NEMS respectively. This region receives a minimum rainfall of 41.2mm and a maximum of 381.8mm, a minimum of 5.2mm and a maximum of 271.0, a minimum of 0.0mm and a maximum of 225.4 mm in the month of October, November and December respectively. During NEMS, it receives a minimum total rainfall of 84.4mm and a maximum total rainfall of 616.6 mm during NEMS

4.4 Sub-region IV : Northeast or north coastal region

Region IV comprises of Chennai, Kanchipuram, Thiruvallur and Vellore districts. Except Vellore, all the other districts are located over north coastal Tamil Nadu and this region may be designated as 'north coastal or northeast region'. This region covers an area of 14108 sq. km. There are 19 rain gauges in the region and the average height of the rain gauges is 104 m amsl. This region receives a mean rainfall of 207.5 mm, 228.7 mm, 97.6 and 533.1mm with standard deviation of 110.2mm, 136.7mm, 109.0mm and 200.5 mm in the month of October, November, December and NEMS respectively. This region receives a minimum rainfall of 10.7mm and a maximum of 566.9 mm, a minimum of 4.6mm and a maximum of 545.1, a minimum of 0.0 mm and a maximum of 569.8 mm in the month of October, November and December respectively. During NEMS, it receives a minimum total rainfall of 106.2mm and a maximum total rainfall of 1212.2 mm during NEMS.

4.5 Sub-region V : South Coastal region

The districts Tirunelveli, Thoothukudi and Kanyakumari make the region V. These districts are located over south coastal Tamil Nadu and this region can be called as 'South coastal region'. This region covers an area of 13116 sq. km. There are 22 rain gauges in the region and the average height of the rain gauges is 66 m a. m. s. l.

This region receives a mean rainfall of 179.4 mm, 200.9 mm, 89.8 and 469.7mm with standard deviation of 76.5mm, 95.8mm, 76.2mm and 154.5 mm in the month of October, November, December and NEMS respectively. This region receives a minimum rainfall of 33.0mm and a maximum of 398.7mm, a minimum of 29.7mm and a maximum of 493.4, a minimum of 0.4mm and a maximum of 379.7 mm in the month of October, November and December respectively. During NEMS, it receives a minimum total rainfall of 157.8mm and a maximum total rainfall of 931.8 mm during NEMS.

Comparing the mean rainfall in the month of October between the regions, the Region 4, which is located in northeast part of the state, receives higher rainfall of 207.5 mm but with higher standard deviation of 110mm while the region3 receives low

mean rainfall of 171 mm with low standard deviation of 69mm. As far as, the mean rainfall in the month of November is concerned, the Region 1, which is located in the central coastal part of the state, receives higher mean monthly rainfall of 207.5 mm but with higher standard deviation of 149 mm while the region3 receives low mean rainfall of 107 mm with low standard deviation of 68mm. In December also, the region1 receives a higher mean monthly rainfall of 157mm with higher standard deviation of 131mm. The standard deviation of region 3 and region 4 is more than the mean monthly rainfall in the month of December i.e., the CV is more than 100%. The region1 receives higher mean NEMR with higher standard deviation of 210mm

4.6 The fragmented regions

The districts namely Villupuram, Thiruvannamalai, Coimbatore, Karur, Tiruchirappalli, Ramanathapuram and Theni are unclassified districts as per strong alignment to any of the five principal components found. Villupuram, which is lying between the Region 4 and 1 and Ramanathapuram, which is located between region 1 and 5, are coastal districts. The districts Coimbatore and Theni are located close the 'Western Ghats' and the rest of the districts are interior districts Each of the sub regions outlined in the figure 6 corresponds to a graphical area where a distinct set of a mechanisms act either to enhance or suppress the rainfall activity. These mechanisms are basically related to the configuration and position of rainfall generating meteorological conditions and weather systems or to the interactions (both enhancing and suppressing) between the topography and the rain bearing air flows.

5. Conclusions

Taking the 29 districts as variables and the daily district rainfall of 2852 days of NEM season (1st October to 31st December) of the period 1965-1996 as observations/cases, S-mode principal component analysis was done. Varimax rotation is done by taking five PCs and it classifies 22 districts in to five groups. Balance of 7 districts are found with weak / moderate relations to any of the PCs either by Varimax rotation. Tamil Nadu is regionalised based on strong relationship with 5 PCs. Sub-region 1 comprises of districts Cuddalore, Perambalur, Pudukottai, Thanjavur, Thiruvarur and Nagapattinam. The districts Madurai, Sivaganga, Virudhunagar and Dindugul make Sub-region II. The districts Dharmapuri, Salem, Namakkal, Karur, Erode, Nilgiris and Coimbatore make Sub-region III and the districts Chennai, Kanchipuram, Vellore and Thiruvallur form Sub-region IV. The group of districts Tirunelveli, Thoothukudi and Kanyakumari make Sub-region V.

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References

Barring, L. 1987, " Spatial patterns of daily rainfall in Central Kenya: application of principal component analysis, common factor analysis and spatial correlation", J. Climate, 7, pp267-290.

Borrell, M. and Sumner, G. N., 1992," Autumn - winter daily precipitation areas in Wales, 1982/83 to 1986-87", Int. J. Climatol., 12,77-102.

Cattel, R.B., 1966, "The Scree test for the number of factors", Multi var. Bebav. Res., 1, pp 245.

Craddock, J.M. and Flood, C. R., 1969," Eigen vectors for representing the 500 mb geopotential surface over northern hemisphere", Quart. J. R. Meteo. Soc., 95, pp476-593.

Fovell, R.G and Fovell, M. C., 1993, " Climatic zones of the conterminous United states defined using cluster analysis", J. Climate, 6, 2103-2135.

Gong, X. and Richman, M. B., 1995, " On the application of cluster analysis to growing season precipitation data in north America east of Rockies", J. Climate, 8, pp897 - 931.

Jolliffe, I. T.,1987, " Rotation of principal components some comments", J. climate, 7, 507 -510.

Kaiser, H. F., 1958, " The Varimax criterion for analytic rotation in factor analysis", psychometrika, 23, pp187-200.

Periago, M. C. Lana, X. Serra, G. and Fernendez Mills, G., 1991, "Precipitation regionalisation, an application using a meteorological net work in Catalonia (NE Spain)", Int. J. Climatol., 11,pp 529-543.

Preisendorfer, R. W., 1988, "Principal component analysis in meteorology and Oceanography".

Richman, M. B., 1981, "Obliquely rotated principal components: An improved meteorological map typing technique", J. Appl. Meteorol., 20, pp1145 - 1159.

Richman, M. B., 1986, "Rotation of principal components", J. Climatol., 6, pp293 - 335.

Richman, M. B., 1987, "Rotation of Principal components: a reply", J. Climatol., 7(5), pp511 - 520.

Romero, R, Ramis, C. and Guijarro,J.A.,1999, "A 30 year (1964 - 1993) daily rainfall data base for the Spanish Mediterranean regions: first exploratory study", int. J. Climatol., 18, pp541-560.

Sumner, G and Bonell M, 1990," The spatial organisation of daily rainfall in Wales during autumn - winter ", Weather, 45, pp174-187.

Sumner, G. Ramis, G. and Giuijano, J. A., 1993," The spatial organisation of daily rainfall over mallorea, Spain", Int. J. Climatol., 13, pp89 - 109.

White, D., Richman, M and Yarnal,B,1991," Climate regionalisation and rotation of principal components", Int. J. Climatol., 11, pp1-25.

Wilks, D. S., 1995, "Statistical methods in the atmospheric sciences an Introduction" Academic press Inc, California.