

Application of L-moments for regional frequency analysis of maximum monthly rainfall in West Bengal, India

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सार - सांख्यिकी सिद्धान्त में किसी भी प्रकार के वितरण को ज्ञात करने के लिए छोटे-छोटे पलों पर आधारित प्राचलों का आकलन करना एक आम धारणा है। परन्तु छोटे-छोटे पलों के आधार पर आकलन करने की पद्धति हमेशा संतोषजनक नहीं होती है। होस्कींग (1990) ने एल-मोमेंट्स (L-moments) के द्वारा प्राचलों के आकलन की एक वैकल्पिक और अधिक संतुलित पद्धति को प्रस्तुत किया है। अनुक्रम सांख्यिकी (order statistics) के कुछ रैखिक संयोजन (Linear combination) में एल-मोमेंट्स की आवश्यकता होती है। इस शोध-पत्र में पश्चिम बंगाल में वर्षा की वजह से भिन्न-भिन्न जिलों की विषमता की जाँच करने के लिए एल-मोमेंट्स पद्धति और पश्चिम बंगाल के उन्हीं जिलों में अधिकतम मासिक वर्षा के क्षेत्रीय आवृत्ति विश्लेषण को अपनाया गया है। इस शोध पत्र में 102 वर्षों (1901-2002) के मॉनसून के महीनों में हुई वर्षा के मासिक डेटा को शामिल किया गया है। विषमता परीक्षण के परिणाम से पता चला है कि पश्चिम बंगाल के 18 जिलों में मॉनसून के महीनों (जून, जुलाई, अगस्त तथा सितम्बर) में समरूप वर्षा नहीं हुई है। इन परिणामों का उपयोग करते हुए इस शोध पत्र में सभी जिलों के लिए वर्षा वापसी की अवधि के क्रमागत प्रवृत्ति की जानकारी के लिए एक सुनियोजित खाका तैयार किया गया है।

ABSTRACT. Moment based method of estimation of parameters for fitting any distribution is a common practice in the theory of statistics. But the method of estimation through moments is not always satisfactory. Hosking (1990) introduced an alternative and more robust method of estimation of parameters by L-moments. L-moments are expectations of certain linear combination of order statistics. In the present study, we apply the above method of L-moments for testing the heterogeneity due to rainfall of different districts in West Bengal and the regional frequency analysis of maximum monthly rainfall in the said districts of West Bengal. The study involves the data for 102 years (1901- 2002) of monthly data for the monsoon months. The result of homogeneity test shows that the 18 districts in West Bengal are not homogenous for the rainfall in monsoon months (June, July, August and September). Using the results, the Return Periods of all the districts under study have been developed with their respective trends for the making the containment structure.

Key words – Order statistics, L-moments, Regional frequency analysis.

1. Introduction

The identification of the pattern of rainfall and estimation of the probabilities of occurrence of the events play a vital role in hydrologic and economic evaluation of water resources projects. Since the conventional statistical methods have been fully utilized for so long, the method based on Regional Frequency Analysis is expected to provide a much better and advanced approach. It helps us to estimate the return periods and their corresponding event magnitudes; thereby creating reasonable criteria for designing of any containment structure.

The basic problem in rainfall studies is the insufficiency of gauging net-work and data, as a result the

classical approach to rainfall analysis is being hampered; especially when we are estimating events of large return periods. The Regional Frequency Analysis assists in solving this information problem.

L-moments for regionalization of hydro-climatic variables have been widely in use in various studies after its introduction by Hosking (1990). The L-moments can be defined as expectations of certain linear combinations of order statistics. They are analogous to conventional moments with measures of location (mean), scale (standard deviation) and shape (skewness and kurtosis). Because L-moments are linear combinations of ranked observations and do not involve squaring or cubing the observations, as is done for the conventional method of

moments estimators, they are generally more robust and less sensitive to outliers. Literature survey reveals that the Regional Frequency Analysis using L-moments are used by several authors [Eslamian and Feizi (2007), Hassan and Ping (2012)].

Regional Frequency Analysis involves the formation of a region that is required to unveil the spatial transfer of information. A region, in this context, means a collection of catchments not necessarily geographically contiguous; that can be considered to be similar in terms of hydrological response. A region can be considered to comprise a group of sites / districts from which extreme rainfall information can be obtained. Thus, the identification of an appropriate group of sites/ districts is an important step in this method.

The present study deals with the L-moments based method of regional frequency analysis of maximum monthly rainfall for the 18 districts of West Bengal over a period of 102 years. The study begins with the calculation of the L-moments and then utilizing the L-moment ratios to compute Homogeneity Measures and the Goodness of fit measurements. The next step of the regional frequency analysis is concerned with the selection of the most appropriate distribution and estimation of the parameters of the fitted distribution together with their uncertainty, using the homogeneous regions.

2. Data base and climatic status of the zone

West Bengal's climate varies from tropical savannah in the southern portions to humid subtropical in the north. The main seasons are summer, rainy season, a short autumn and winter. Monsoons bring rain to the whole state from June to September.

Data source : Monthly rainfall data (mm) over the study area (18 districts of West Bengal) was obtained from the website http://indiawaterportal.org/met_data/ for the period 1901-2002.

Software used : The data analysis has been done by using R- package (Ver. 2.15.1).

3. Methodology

3.1. L-moments

The L-moments are the summary statistics for probability distributions and data samples and are analogous to ordinary moments (Hosking, 1990). They provide measures of location, dispersion, skewness, kurtosis, and other aspects of the shape of probability distributions or data samples. Each statistical

L-moment is computed linearly (hence the L) giving a more robust estimate for a given amount of data than other methods.

Definition : For the random variables X_1, \dots, X_n of sample size n drawn from the distribution of a random variable X with the mean m and variance of s^2 , let $X_{1:1} \leq \dots \leq X_{1:n}$ be the order statistics such that the L-moments of X are defined by:

$$\lambda_r \equiv r^{-1} \sum_{k=0}^{r-1} (-1)^k \binom{r-1}{k} E[X_{r-k:r}], \quad r=1,2,\dots \quad (1)$$

where, r is the r -th L-moment of a distribution and $E[X_{i:r}]$ is the expected value of the i th smallest observation in a sample of size r .

The first four L-moments of a random variable X can be written as

$$\lambda_1 = E[X], \quad (2)$$

$$\lambda_2 = (1/2) E[X_{2:2} - X_{1:2}], \quad (3)$$

$$\lambda_3 = (1/3) E[X_{3:3} - 2X_{2:3} + X_{1:3}], \quad (4)$$

$$\lambda_4 = (1/4) E[X_{4:4} - 3X_{3:4} + 3X_{2:4} - X_{1:4}] \quad (5)$$

Hosking (1990) demonstrated the utility of estimators based on the L-moment ratios in hydrological extreme analysis. The second moment is often scaled by the mean so that a coefficient of variability (LC_v) is determined:

$$\tau = LC_v = \frac{\lambda_2}{\lambda_1} \quad (6)$$

where, λ_1 is the measure of location. Similar to the definitions and the meaning of the ratios between ordinary moments, the coefficients of L-kurtosis and L-skewness are defined as:

$$\tau_r = \frac{\lambda_r}{\lambda_2}, \quad r \geq 3 \quad (7)$$

where, τ_3 is the measure of skewness (LC_S) and τ_4 is the measure of kurtosis (LC_k). Unlike standard moments, τ_3 and τ_4 are constrained to be between -1 and +1, and τ_4 is constrained by τ_3 to be no lower than -0.25. Because precipitation is nonnegative, τ is also constrained to the range from 0 to 1. The computation of the L-moments has been displayed in Table 1.

TABLE 1
Computation of D-statistic

| No. | District | Period (yr) | First L-moment | τ | τ_3 | τ_4 | D_i |
|-----|-----------------|-------------|----------------|--------|----------|----------|-------|
| 1. | Nadia | 102 | 386.604 | 0.111 | 0.093 | 0.134 | 1.10 |
| 2. | Hooghly | 102 | 419.222 | 0.144 | 0.168 | 0.160 | 0.56 |
| 3. | Kolkata | 102 | 435.774 | 0.151 | 0.187 | 0.166 | 1.03 |
| 4. | Birbhum | 102 | 392.504 | 0.129 | 0.116 | 0.083 | 2.78 |
| 5. | Bardhaman | 102 | 387.556 | 0.124 | 0.114 | 0.121 | 0.09 |
| 6. | Bankura | 102 | 392.247 | 0.127 | 0.074 | 0.117 | 0.80 |
| 7. | Dakshindinajpur | 102 | 417.344 | 0.126 | 0.116 | 0.122 | 0.08 |
| 8. | Darjeeling | 102 | 595.634 | 0.116 | 0.140 | 0.120 | 0.52 |
| 9. | Howrah | 102 | 435.851 | 0.148 | 0.187 | 0.163 | 0.84 |
| 10. | Jalpaiguri | 102 | 638.763 | 0.109 | 0.158 | 0.111 | 1.77 |
| 11. | Coochbehar | 102 | 562.674 | 0.117 | 0.185 | 0.163 | 2.46 |
| 12. | Maldah | 102 | 395.185 | 0.124 | 0.118 | 0.107 | 0.52 |
| 13. | Midnapur | 102 | 417.851 | 0.126 | 0.146 | 0.134 | 0.09 |
| 14. | Murshidabad | 102 | 394.269 | 0.112 | 0.088 | 0.116 | 0.53 |
| 15. | North24parganas | 102 | 434.252 | 0.146 | 0.163 | 0.148 | 0.59 |
| 16. | South24parganas | 102 | 382.976 | 0.152 | 0.182 | 0.168 | 1.10 |
| 17. | Purulia | 102 | 380.062 | 0.124 | 0.036 | 0.134 | 2.79 |
| 18. | Uttardinajpur | 102 | 437.605 | 0.117 | 0.089 | 0.117 | 0.35 |

TABLE 2
Computation of H-statistic

| No. of simulations | No. of districts | Test statistic H ₁ | Test statistic H ₂ | Test statistic H ₃ |
|--------------------|------------------|-------------------------------|-------------------------------|-------------------------------|
| 500 | 18 | 3.29* | 0.69 | -0.31 |

[* implies heterogeneity]

TABLE 3
Computation of z-statistic

| Gen. logistic | Gen. extreme value | Gen. normal | Pearson type III | Gen. Pareto |
|---------------|--------------------|-------------|------------------|-------------|
| 6.34 | 0.52** | 0.49** | -0.58** | -11.75 |

[** implies fitted distributions]

3.2. Application of L-moments

In Regional Frequency Analysis, it is necessary that all the sites/districts located in one region have data with the same probability distribution. For this reason, before performing regional analysis, the homogeneity of the region should be tested. Hosking and Wallis (1991) provide two statistics for a test of homogeneity. The tests are Discordancy Test and Homogeneity Measure.

3.3. Discordancy test

The Discordancy measure, D_i , is based on the L-moments and can be used to determine an unusual sites/district. D_i is defined as:

$$D_i = \frac{1}{3} (u_i - \bar{u})^T s^{-1} (u_i - \bar{u}) \tag{8}$$

where, $u_i = [t^{(i)}, t_3^{(i)}, t_4^{(i)}]^T$ is the vector of sample L-moments ratios, for a site / district i , $t =$ sample LC_v

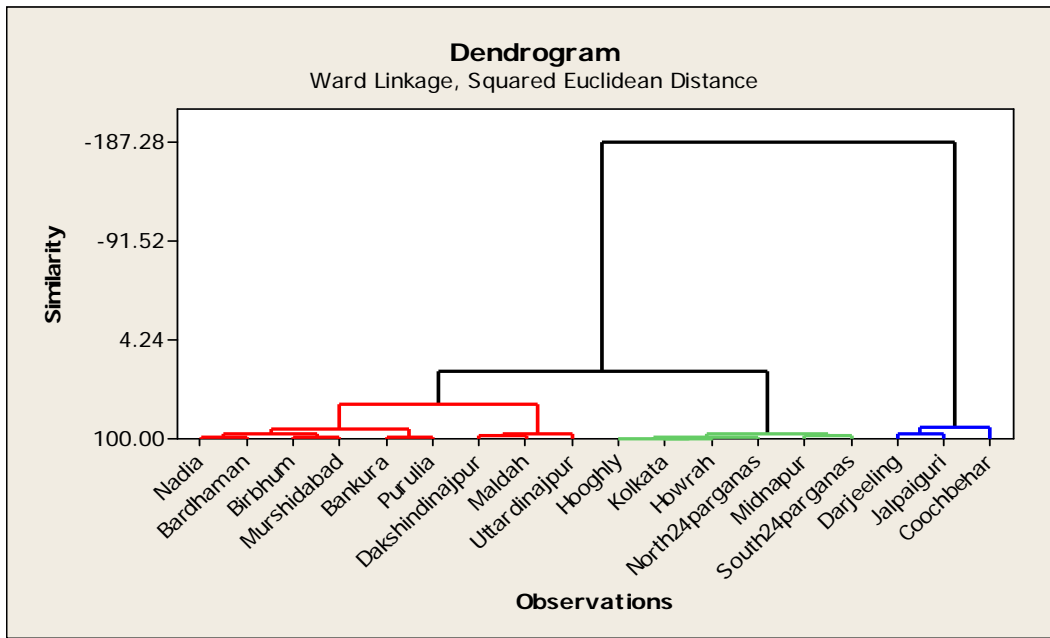


Fig. 1. Cluster analysis

(estimated value of τ), t_3 = sample LC_s (estimated value of τ_3) and t_4 = sample LC_k (estimated value of τ_4), superscript T denotes the transposition of a vector or matrix.

$$s = (N_s - 1)^{-1} \sum_{i=1}^{N_s} (u_i - \bar{u})(u_i - \bar{u})^T \quad (9)$$

$$\bar{u} = N_s^{-1} \sum_{i=1}^{N_s} u_i \quad (10)$$

N_s is the total number of sites/districts. If the D_i exceeds 3, the site/district is considered as a discordant station (Hosking and Wallis, 1991).

The D statistic for all 18 districts of West Bengal have has been calculated as shown in Table 1. Results show that the critical value, $D_i < 3$ for the districts of West Bengal. Next, we try for the second test of homogeneity measurement.

3.4. Homogeneity measure (H)

The H statistic is a measure of heterogeneity which estimates the degree of heterogeneity in a group of sites/districts and evaluates whether these sites/ districts are reasonably homogeneous. In fact, this statistic compares the variations of L-moments of sites/ districts for a group of these sites/ districts with the expected values of variations for a homogeneous region.

The three measures of variability, V_1 , V_2 and V_3 will be estimated by using the following equations. The weighted standard deviation of t, based on sample LC_v is

$$V_1 = \frac{\sum_{i=1}^{N_s} N_i [t^{(i)} - \bar{t}]^2}{\sum_{i=1}^{N_s} N_i} \quad (11)$$

where, N_s is the total number of sites/districts, N_i is the length of records at each site/ district and \bar{t} is average of $t^{(i)}$ values computed by

$$\bar{t} = \frac{[\sum_{i=1}^{N_s} N_i t^{(i)}]}{[\sum_{i=1}^{N_s} N_i]} \quad (12)$$

The weighted average distance between the sites/districts and weighted average of the group can be estimated by V_2 and V_3 based on sample LC_v , LC_s and LC_k as

$$V_2 = \frac{\sum_{i=1}^{N_s} N_i \{ [t^{(i)} - \bar{t}]^2 + [t_3^{(i)} - \bar{t}_3]^2 \}^{1/2}}{[\sum_{i=1}^{N_s} N_i]} \quad (13)$$

$$V_3 = \frac{\sum_{i=1}^{N_s} N_i \{ [t_3^{(i)} - \bar{t}_3]^2 + [t_4^{(i)} - \bar{t}_4]^2 \}^{1/2}}{[\sum_{i=1}^{N_s} N_i]} \quad (14)$$

TABLE 4
Group wise rainfall analysis

| Region (No of Districts) | Districts | Mean of L-moments | | | H statistics | | | Distribution (parameters) | Z value |
|-----------------------------|--|-------------------|-----------------|-----------------|----------------|----------------|----------------|---------------------------|----------|
| | | LC _v | LC _s | LC _k | H ₁ | H ₂ | H ₃ | | |
| GROUP-1 (9) | Nadia, Birbhum, Bankura, Bardhaman, Maldah, Dakshindinajpur, Purulia, Murshidabad,Uttardinajpur | | | | | | | GL | 5.85 |
| | | | | | | | | GEV(0.909 0.194 0.122) | 0.90 ** |
| | | 0.121 | 0.093 | 0.116 | -0.66 | -1.34 | -2.18 | GN(0.979 0.212 -0.192) | 1.34 ** |
| | | | | | | | | P-III(1.00 0.217 0.573) | 0.91 ** |
| | | | | | | | | GP | -9.06 |
| GROUP-2 (6) | Hooghly, Kolkata, Howrah, Midnapur, North24parganas, South24parganas | | | | | | | GL | 2.23 |
| | | | | | | | | GEV(0.879 0.207 -0.003) | -0.42 ** |
| | | 0.144 | 0.172 | 0.156 | -0.38 | -2.03 | -2.52 | GN(0.955 0.243 -0.354) | -0.78 ** |
| | | | | | | | | P-III | -1.69 |
| | | | | | | | | GP | -6.34 |
| GROUP-3 (3) | Darjeeling, Jalpaiguri, Coochbehar | | | | | | | GL | 2.94 |
| | | | | | | | | GEV(0.906 0.166 0.013) | 0.79 ** |
| | | 0.113 | 0.161 | 0.131 | -0.75 | -0.8 | -0.7 | GN(0.967 0.193 -0.331) | 0.59 ** |
| | | | | | | | | P-III(1.00 0.208 0.978) | -0.05 ** |
| | | | | | | | | GP | -3.92 |

GL- Gen. Logistic, GEV- Gen. Extreme value, GN- Gen. Normal, P-III- Pearson type III, GP- Gen. Pareto

[** implies fitted distributions]

By fitting a four-parameter kappa distribution (Hosking and Wallis, 1988), using simulations, we can compute the heterogeneity measure by

$$H_i = \frac{V_i - \mu_v}{\sigma_v} \tag{15}$$

where, μ_v and σ_v are the mean and standard deviation of the simulated data, respectively. Hosking and Wallis (1997) used the four-parameter kappa distribution to generate artificial data for assessing the goodness of fit for different distributions. Hosking and Wallis (1997) suggested that a region is reasonably homogeneous if $H_i < 1$ and that a region is fairly homogeneous if $1 \leq H_i \leq 2$. If any of the $H_i > 2$, then the region is absolutely heterogeneous and $I = 1, 2, 3$.

3.5. Goodness-of-fit test

Hosking and Wallis (1997) presented a measure of goodness of fit based on sample average regional kurtosis \bar{t}_4 . The goodness-of-fit measurement is used to identify the regional parent distribution. This statistic, z^{DIST} , is a

measure of goodness-of-fit that judges the difference between sample LC_k and population LC_k for the fitted distribution, can be written as

$$Z^{DIST} = \frac{\bar{t}_4 - \tau_4^{DIST}}{\sigma_4} \tag{16}$$

where, σ_4 is the standard deviation of \bar{t}_4 . The value of σ_4 can be computed by simulation after fitting a kappa distribution to the data (Hosking and Wallis 1988). A given distribution is declared a good fit if $|z^{DIST}| \leq 1.64$ (Hosking and Wallis, 1988).

3.6. Parameter estimation

Regional frequency analysis involves the problem of estimation, from a random sample of size n , of a probability distribution whose specification involves a finite number p of the unknown parameters. The method of L-moments obtains parameters by equating the first p sample L-moments to the corresponding population quantiles which is analogous to the ordinary method of moments.

TABLE 5
GEV Parameters and Return Periods for each District

| S. No. | Districts | GEV Parameters | | | Return period (year) | | | | | | | |
|--------|-----------------|----------------|----------|---------|----------------------|--------|--------|--------|--------|---------|---------|--|
| | | k | α | μ | 2 | 5 | 10 | 15 | 25 | 50 | 100 | |
| 1. | Nadia | 0.124 | 68.394 | 354.679 | 430.97 | 493.22 | 529.71 | 549.14 | 571.05 | 598.64 | 628.05 | |
| 2. | Hooghly | 0.003 | 87.185 | 369.153 | 473.64 | 571.86 | 636.38 | 673.29 | 717.33 | 776.98 | 846.62 | |
| 3. | Kolkata | -0.026 | 92.840 | 379.730 | 492.96 | 603.06 | 677.39 | 720.64 | 772.95 | 845.07 | 931.11 | |
| 4. | Birbhum | 0.085 | 78.567 | 353.313 | 442.97 | 519.51 | 566.04 | 591.40 | 620.51 | 658.03 | 699.20 | |
| 5. | Bardhaman | 0.089 | 74.979 | 350.355 | 435.76 | 508.40 | 552.44 | 576.38 | 603.84 | 639.16 | 677.83 | |
| 6. | Bankura | 0.156 | 81.587 | 356.218 | 445.54 | 515.73 | 555.64 | 576.49 | 599.65 | 628.26 | 658.03 | |
| 7. | Dakshindinajpur | 0.086 | 81.341 | 376.827 | 469.60 | 548.73 | 596.80 | 622.97 | 653.02 | 691.73 | 734.17 | |
| 8. | Darjeeling | 0.047 | 104.063 | 540.195 | 661.69 | 770.17 | 838.56 | 876.68 | 921.25 | 980.03 | 1046.43 | |
| 9. | Howrah | -0.027 | 90.405 | 381.172 | 491.51 | 598.93 | 671.53 | 713.80 | 764.96 | 835.52 | 919.78 | |
| 10. | Jalpaiguri | 0.018 | 101.671 | 581.874 | 702.62 | 814.12 | 886.33 | 927.27 | 975.77 | 1040.88 | 1116.01 | |
| 11. | Coochbehar | -0.023 | 92.666 | 506.997 | 619.83 | 729.19 | 802.84 | 845.62 | 897.31 | 968.44 | 1053.13 | |
| 12. | Maldah | 0.084 | 76.068 | 357.118 | 444.02 | 518.37 | 563.65 | 588.35 | 616.74 | 653.36 | 693.61 | |
| 13. | Midnapur | 0.038 | 78.701 | 375.248 | 467.64 | 551.05 | 604.10 | 633.83 | 668.74 | 715.05 | 767.73 | |
| 14. | Murshidabad | 0.133 | 70.856 | 361.681 | 440.32 | 503.85 | 540.78 | 560.34 | 582.32 | 609.85 | 639.00 | |
| 15. | North24parganas | 0.011 | 92.136 | 382.092 | 491.97 | 594.23 | 660.90 | 698.84 | 743.94 | 804.72 | 875.23 | |
| 16. | South24parganas | -0.019 | 82.689 | 333.635 | 434.08 | 530.97 | 595.98 | 633.65 | 679.08 | 741.45 | 815.48 | |
| 17. | Purulia | 0.220 | 80.038 | 348.435 | 432.90 | 494.53 | 527.52 | 544.11 | 562.01 | 583.30 | 604.41 | |
| 18. | Uttardinajpur | 0.131 | 82.380 | 399.573 | 491.12 | 565.27 | 608.46 | 631.37 | 657.13 | 689.45 | 723.73 | |

The exact distribution of parameter estimators obtained by this method is difficult to derive in general. However by treating the estimators as a function of sample L-moments and applying Taylor series methods, asymptotic distributions can be obtained. For estimating parameters, first the shape parameter of the distribution should be estimated from regional weighted L-moments. In this, all of the sites/ districts that are in one region should have the same shape parameter value. After the estimation of the shape parameter, the other parameters will be estimated. Hosking and Wood (1985) and Hosking and Wallis (1987) found that asymptotic approximations are usually reliable for samples of 50 or more.

As indicated by all the tests our selected distribution is therefore generalized extreme value (GEV) distribution. The probability density function of this distribution is

$$f(x) = \alpha^{-1} \left\{ 1 - k \left[\frac{k - \mu}{\alpha} \right] \right\}^{\left(\frac{1}{k}\right)^{-1}} \exp \left\{ - \left\{ 1 - k \left[\frac{(x - \alpha)}{\alpha} \right] \right\}^{\frac{1}{k}} \right\}$$

The parameter estimators of this distribution are:

$$\hat{k} \approx 7.8590 z + 2.9554 z^2 \tag{17}$$

$$\hat{\alpha} = l_2 \hat{k} (1 - 2^{-k}) \Gamma(1 + \hat{k}) \tag{18}$$

$$\hat{\mu} = l_1 + \frac{\hat{\alpha} [\Gamma(1 + \hat{k}) - 1]}{\hat{k}} \tag{19}$$

where, $z = 2/(3 + t_3) - \log 2 / \log 3$, k is shape parameter, α is scale parameter and μ is location parameter.

3.7. Cluster analysis

Conventional multivariate technique such as cluster analysis with hydrologic variables is to group observations or variables into clusters based on the high similarity of hydrologic features, such as geographical, physical, statistical or stochastic properties. So, each cluster contains the least variance of variables (smallest dissimilarity). In present study, the hierarchical cluster

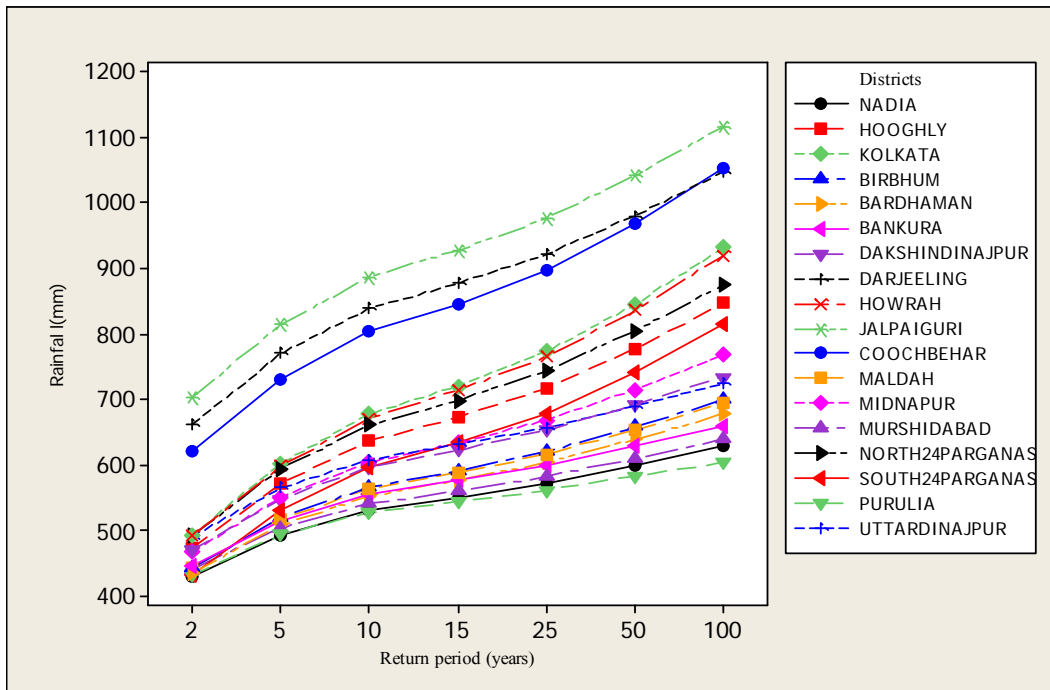


Fig. 2. Return period plots for each district

technique is applied to classify the rainfall sites into spatial groups.

Several methods have been proposed for hierarchical cluster analysis, including single, average and complete linkage, and Ward's method (minimum variance). The Ward's method gives better results than other methods of classification (Hassan, and Ping, 2012). Therefore, Ward's method is used in the present study for cluster analysis of rainfall data in West Bengal. In Ward's method, the distance between two clusters is calculated as the sum of squares between two clusters, added up over all variables. The sum of squares of each cluster has been minimized for generation of a cluster.

The cluster and L-moment methods are used together in order to find the spatial rainfall regions and the regional rainfall frequency for each region, respectively. The L-moments are applied to see the homogeneity of these classified groups and to find the regional frequency distribution for each group.

4. Results and discussion

Table 3 shows that the GEV, Gen. Normal and Pearson Type III are the best fitted distributions for the 18 districts of West Bengal. However, in the present study we

go for fitting the distribution GEV only for getting return periods. Since Table 2 indicates from the value of H_1 that there is heterogeneity in rainfall in the state of West Bengal. On the basis of Ward's method in cluster analysis, the 18 districts of West Bengal can be classified into three groups Fig. 1.

The analysis was carried out for each group using 500 simulations and from Table 4 confirms the homogeneity of the clustered group's base on the H statistics. The GEV distribution is found best fitted for all the groups. The estimated parameter values of GEV distribution for the different groups are given in Table 4 and for each district in Table 5.

The theoretical return period is the inverse of the probability that the event will be exceeded in any one year (or more accurately the inverse of the expected number of occurrences in a year). Return Periods of all the districts have been summarized in Table 5 and their respective trends in Fig. 2.

5. Conclusion

Analyzing the rainfall data of West Bengal, it is clear that the application of the L-moments is very much useful and robust technique for confirming either similarities or

dissimilarities in the regional frequency analysis of the rainfall events. It also reveals the robustness of the parameter estimation and hence one can obtain more reliable return periods. As we know that the districts of West Bengal are not homogeneous in rainfall, which have been clearly illustrated by the Homogeneity measures and cluster analysis. The Hilly and Terai areas consisting of Darjeeling, Jalpaiguri and Cooch Behar forms a separate cluster. Another cluster is consisting the districts of the Gangetic plain and the central parts of the state. The remaining districts of lower gangetic plains and coastal parts form the third cluster. Rainfall in the Hilly and Terai areas varies largely from the other districts. The coastal areas have almost same rainfall as that of the Gangetic plain and central parts of the state. There are chances of flood in the hills and drought in the western plateau area. So accordingly the containment structure should be designed. Thus the application of cluster analysis together with L-moment method is highly justified in different geographical and climate regions to prove the relationship between rainfall regimes and rainfall distribution functions.

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