Regionalization of Maximum Daily Rainfall data over Tokat Province, Turkey

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Abstract

The estimation of annual maximum rainfall in the region where no data is available is important for hydrologic design. In this study, the method of L-moments was applied for fitting regional distribution for annual maximum rainfall in Tokat region. As no significant relationship between rainfall and elevation of the stations was found, the region was first divided into two regions but they were not homogeneous. Thus, the region was divided into three regions that were found to be homogeneous. The use of goodness of fit test showed that Generalized Logistic and Generalized Extreme Values distribution are the best regional distributions for homogeneous regions.

Key words: Maximum Rainfall, L-moments, discordancy, heterogeneity test, GLOG, GEV, Tokat Region

INTRODUCTION

Estimates of extreme rainfalls are not only important for flood estimation but also for hydrologic engineering and hydraulic designing. Thus, extreme rainfall depth-frequency analysis has a key role in the design of hydraulic structures where a return period is selected according to the cost and economic/strategic significance of the structure [1]. In this case, reliable design quantile estimation is usually essential which affect on design and management of hydraulic structures considerably depends on statistical methods used in parameter estimation belonging to probability distributions [2, 3, 4].

Techniques used in at-site hydrologic and climatic frequency analysis are widely documented [5, 6]. However, like other hydrologic and atmospheric phenomenon, hydrologists and hydraulic designers have always concerned with a common problem in rainfall estimation at ungaged sites as well as fitting frequency distribution and regionalizing extreme rainfall statistics to ungaged regions. Regional frequency analysis assumes that the standardized variate has the same distribution at every site in the selected homogeneous region and that data from a region can thus be combined to produce a single regional rainfall frequency curve [7, 8]. This approach can also be used to estimate events at an ungauged site where no information exists [9]. There are a lot of literatures that have expressed the efficiency of hydrologic regionalization in comparison with at site frequency analysis [10, 11, 8, 1].

After introducing the concept of probability weighted moments (PWMs) by Greenwood et al. [12], Hosking [13, 14] defined L-moment which is equivalent to PWM as L-moments can be expressed by linear combinations of PWMs. This method has then been widely used in hydrologic and climatic regionalization [15, 16, 17, 18, 19].

Yürekli [20] divided Tokat and Amasya provinces into four and three hydrologic homogeneous sections based on station-year technique, respectively, and suitable probability distributions for monthly and annual daily extreme rainfall depths and monthly rainfall depths recorded in the sections were determined. Topaloğlu [21] tried to determine suitable probability distribution for daily rainfalls occurred on Seyhan river basin. For this purpose, by using the method of moment (MOM) and probability weighted moment (PWM) for parameter estimation, Gumbel (MOM) and log-Pearson-3 distributions based on chi-square and Kolmogorov-Smirnov goodness- of- fit tests were found for daily rainfalls on the basin, respectively. Okman [22] used plotting position formulas for the reoccurrence probability of monthly rainfall values recorded on Ankara Province that was divided into four hydrologic homogeneous sections by using station-year method. Balaban et all. [23] took into consideration extreme value type I, logarithmic normal and Pearson type III probability distributions to determine the most suitable method of estimation the daily maximum rainfall frequencies in Urfa region. The logarithmic normal distribution has been selected as base method for estimating the daily maximum rainfall depths in Urfa Province. Okman [24] used ploting position formulas and normal, logarithmic normal, extreme value type I and Pearson type III probability distribution to determine the most suitable method for estimation the intensive daily rainfall frequency that create a surface drainage problem in Cubuk Creek watershed. Extreme value type I was selected as base method for estimating the intensive daily rainfall depths in the watershed.

The overall objective of this study is to establish an annual daily maximum rainfall magnitude with any return period of occurrence using L-moments. In order to achieve this by using daily maximum rainfalls over Tokat Province, delineating homogeneous regions based on homogeneity measure of site characteristics and identification of suitable regional frequency distribution were included in the study.

METHODOLOGY

The Study Area

Tokat province selected as study area is bounded 39º 45' N and 40º 45' N latitudes, 35º 30' E and 37º 45' E longitudes, covering approximately 10160.7 km^2. About 30% of the area is occupied by cropland. Wheat is the major food crop (average sowing area is 68.5% of the total cropped area) not only in the district, but in the entire Turkey. The major source of irrigation is rainfall, canal and groundwater. Annual daily maximum rainfalls used in the study was selected among daily rainfall amounts recorded in the rainfall gauge stations controlled by Turkish State Meteorological Service and General Directorate of State Hydraulic Works. The approximate location of the rainfall gauge stations was given in Figure 1.

Review of L-moment Method

Probability weighted moments were defined by Greenwood et al. [12] as follows:

$$\beta_r = \sum_{k=0}^{r} \binom{r}{k} (-1)^k \alpha_k \qquad (5)$$

Hosking and Wallis [13, 14] defined the L-moments λ_{r+1} in terms of α_s and β_r as follows:

$$\lambda_{r+1} = (-1)^r \sum_{k=0}^{r} p^*_{r,k} \alpha_k = \sum_{k=0}^{r} p^*_{r,k} \beta_k \qquad (6)$$

where

$$p^*_{r,k} = (-1)^{r-k} \binom{r}{k} \binom{r+k}{k} \qquad (7)$$

The unbiased PWM samples are then calculated from the following equations:

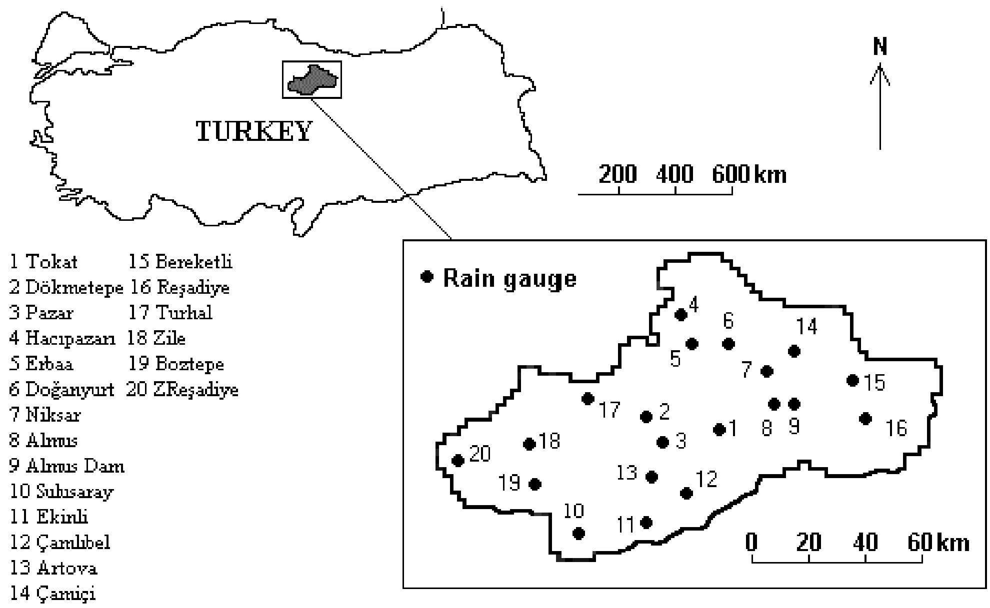

Figure1. Rainfall Gauge Station over Tokat Province

$$M_{p,r,s} = \int_o^1 [(F)]^p F^r (1-F)^2 \, dF \qquad (1)$$

The following two moments are usually considered [25]:

$$M_{1,o,s} = \alpha_s = \int_o^1 x(F)(1-F)^s \, dF \qquad (2)$$

$$M_{1,r,o} = \beta_r = \int_o^1 x(F) F^r \, dF \qquad (3)$$

Also, α_s and β_r are related to each other as follows:

$$\alpha_s = \sum_{k=0}^{s} \binom{s}{k} (-1)^k \beta_k \qquad (4)$$

,

$$a_s = \frac{1}{n} \frac{\sum_{i=1}^{n} \binom{n-i}{s} x_i}{\binom{n-1}{s}} \qquad (8)$$

$$b_s = \frac{1}{n} \frac{\sum_{i=1}^{n} \binom{i-1}{r} x_i}{\binom{n-1}{r}} \qquad (9)$$

Sample L-moments are calculated by substituting sample estimates of a_s and b_s in the place of α_s and β_s in equation 6.

As an alternative, plotting position estimators of sample PWMs are obtained from the following equations:

$$a_s = \hat{\alpha}_s = \frac{1}{n}\sum_{i=1}^{n}(1 - P_{i:n})^s x_i \quad (10)$$

$$b_r = \hat{\beta}_r = \frac{1}{n}\sum_{i=1}^{n} P_{i:n}{}^r x_i \quad (11)$$

where $P_{i:n}$ = plotting position. Plotting position is a tool for visual evaluation of compare sample and population frequency distribution. It is suggested to use $P_{i:n} = (i - 0.35)/n$ for generalized extreme value (GEV) [26] and Generalized Pareto [27] as it gives better estimates of parameters [25]. L-moment ratios are then defined by Hosking [13, 14] in (12) and (13):

$$\tau = \lambda_1 / \lambda_2 \quad (12)$$

$$\tau_r = \lambda_r / \lambda_2 \qquad r \geq 3 \quad (13)$$

where λ_1 is measure of the location, τ is measure of scale and dispersion (LCv), τ_3 is measure of skewness (LCs) and τ_4 is measure of kurtosis (LCk). The moment ratio diagram (MRD) is an easy way to identify regional homogeneity of a region. Rao and Hamed [25] used MRD to identify homogenous regions of Wabash river basin for flood frequency analysis. Kroll and Vogel [28] used sample estimates of LCv versus LCs for 7-day low flows in the United States. An L-moment diagram provides a visual comparison of sample estimates to population values of L-moments [5] and is always preferred to product moment ratio diagrams for goodness-of-fit test [29].

Screening of the data

The aim of this stage is to form groups of stations that satisfy the homogeneity condition, those stations with frequency distributions that are identical apart from a station–specific scale factors. This is usually carried out by dividing the sites into disjoint groups. Hosking and Wallis [8] present a discordancy measure. In this approach, the L-moments ratio (L-coefficient of variation, L-skewness and L-kurtosis) of a site is used to describe that site as a point in three-dimensional space. A group of homogeneous sites will form a cluster of such points. If any point does not appear to belong to the cluster of such points on the L-moment diagram, that is, is far from the center of the cluster, the site related to that point should be removed from the region due to non-homogeneity condition. Discordancy measure (Di) of a site can be calculated by

$$\bar{u} = N^{-1}\sum_{i=1}^{N} u_i \quad (14)$$

$$S = (N-1)^{-1}\sum_{i=1}^{N}(u_i - \bar{u})(u_i - \bar{u})^T \quad (15)$$

$$D_i = \frac{1}{3}(u_i - \bar{u})^T S^{-1}(u_i - \bar{u}) \quad (18)$$

Let $u_i = [\tau_2^i, \tau_3^i, \tau_4^i]^T$ be a vector related to L-moment ratios of site i. Where N is the number of sites. Generally, any site with Di > 3 is considered as discordant. In such a case, the site may properly belong to another region.

Heterogeneity Test for Regions

Heterogeneity (H) test by Hosking and Wallis [30], which compares the inter-site variation (dispersion) in sample L-moments for the group of sites, is used to assess whether the regions proposed as homogeneous according to discordancy measure of site characteristics are reasonably treated as a homogeneous region. For this reason, the method fit the four-parameter Kappa distribution to the regional average L-moment ratios to generate 500 homogeneous regions with population parameters equal to the regional average sample L-moment ratios. The properties of the actual region are compared to the simulated homogeneous region. The heterogeneity (H) statistic and V statistic for the sample and simulated regions take the form, respectively:

$$H = (V_{obs} - \mu_V)/\sigma_V \quad 19)$$

$$V = \left\{ \frac{\sum_{i=1}^{N} n_i (\tau_2^i - \tau_2^R)^2}{\sum_{i=1}^{N} n_i} \right\}^{1/2} \quad (20)$$

n_i is record length at site i, τ_2^i is the sample L-coefficient of variation (LCv), τ_2^R is the regional average sample LCv, μV is the mean of simulated V values, σV is the standard deviation of simulated V values. The value of H-statistic indicate that the region under consideration is acceptably homogeneous when H<1, possibly heterogeneous when 1≤ H <2, and definitely heterogeneous when H ≥2 [8].

Choosing the Best Fit Frequency Distribution

In regional frequency analysis, a single frequency distribution is fit to the data from several sites in a homogeneous region. Hosking and Wallis [8] proposed an appropriate method for goodness of fit criterion based on L-kurtosis. This statistic is termed as the Z-statistic:

$$Z^{DIST} = (\tau_4^{DIST} - \bar{\tau}_4 + \beta_4)/\sigma_4 \quad (21)$$

$$\beta_4 = N_{sim}^{-1}\sum_{m=1}^{N_{sim}}(\bar{\tau}_{4m} - \bar{\tau}_4) \quad (22)$$

$$\sigma_4 = \left\{ (N_{sim} - 1)^{-1}\sum_{m=1}^{N_{sim}}(\bar{\tau}_{4m} - \bar{\tau}_4)^2 - N_{sim}\beta_4^2 \right\}^{1/2} \quad (24)$$

Where DIST refers to a candidate statistical distribution, τ_4^{DIST} is the population L-kurtosis of selected distribution, $\bar{\tau}_4$ is the regional average sample L-kurtosis, β_4 is the bias of regional average sample L-kurtosis, σ_4 is the standard deviation of regional average sample L-kurtosis, and Nsim is realizations of a region with N sites. The four parameter Kappa distribution is used to simulate 500 regions similar to the actual region to estimate $\hat{a}_4$ and σ_4. The $|Z^{DIST}| \leq 1.64$ should be for an appropriate regional distribution. But, the distribution giving the minimum $|Z^{DIST}|$ is considered as the best-fit distribution for the region. The regional frequency analysis of annual maximum daily rainfall depths over Tokat Region was achieved by using the FORTRAN routines developed by Hosking [31].

RESULTS AND DISCUSSION

Descriptive analysis

In the first step, the descriptive analysis and the physical relationship of annual maximum rainfall of Tokat region are calculated. The annual maximum rainfall statistics are given in Table 1. In this table, the average annual maximum rainfall is 32.5 for the region. The mean annual maximum rainfall differs from 40.81 at Çamiçi station to 25.07 at Çamlıbel station. The coefficient of variation (Cv), which shows the year-to-year variation of maximum rainfall, differs from 19% to 43%, with the average of 30%. This shows that the year to year variation of maximum rainfall is not significant for the stations in the region. The coefficient of skewness (Cs), which shows the symmetry of the maximum rainfall distribution and is equal to zero for Normal distribution, varies from -0.08 to 2.33 with the mean of 1.23. The coefficient of kurtosis, which shows the peakedness of distribution and is equal to 3 for normal distribution, differs from -1.28 to 9.42 with the mean of 2.42. Both coefficients of skewness and kurtosis reject the Normal distribution for annual maximum rainfall.

To investigate the physical variation of annual maximum rainfall, the correlation coefficient between the elevation of the station and annual maximum rainfall statistics was calculated. For all statistics, no significant relationship was found. This implies that the annual maximum rainfall does not change with the elevation of the stations in the region.

L-moments diagrams

Figures 2 and 3 show the L-moment ratio diagrams (MRDs) for all stations in the region. A high degree of heterogeneity can be identified from the MRDs. Data points are widely scattered in Figures 2 and 3. Two statistics introduced by Hosking and Wallis [30] as alternative methods to identify regional homogeneity are discussed in the following section. Theoretical relationships among L-Cv and LCs in Fig. 2 and LCs and LCk in Fig. 3 were constructed using the FREQ program developed by Rao and Hamed [32] for flood regional frequency analysis.

The distribution of the stations around the mean, shown with "+" sign, in the L-moment diagrams shows a possibility of having two or three regions within Tokat region. The homogeneity of these possible regions should be checked by using the heterogeneity measure, H_i.

Homogeneity and Discordancy Test

The homogeneity and discordancy measures were calculated for possible regions derived from visual inspection of L-moment diagrams (Figures 2 and 3). In this first case, we consider two groups. In the second case, we consider three groups.

Two Groups

In the first attempt, we divide the region into two groups based on the nearest values of L-moments of Figure 2 and 3. Table 2 shows the stations included in these two groups and their L-moments.

Table 1. Descriptive Statistic of annual maximum rainfall of Tokat Region

Station	Min(mm)	Max(mm)	Mean(mm)	STDEV(mm)	CV	CS	CK	Elevation(m)
Tokat	15.5	62.5	30.34	9.8	0.32	1.16	1.6	608
Zile	13.2	86	31.73	10.77	0.34	2.19	9.42	700
Turhal	18	59	32.83	9.43	0.29	0.89	0.67	500
Erbaa	19.2	81.2	33.97	11.82	0.35	1.95	5.14	230
Niksar	18.2	73.8	32.94	10.49	0.32	1.5	3.45	350
Boztepe	21.2	54.5	36.83	10.79	0.29	0.25	-1.28	750
Pazar	18.8	66	29.65	10.78	0.36	2.33	6.59	540
Çamiçi	27.3	67.5	40.81	11.8	0.29	1.3	1.31	1250
Almus Dam	17	78	33.34	13.08	0.39	2.07	5.46	900
Dökmetepe	16.8	42	29.91	6.9	0.23	-0.08	-0.6	635
Almus	23	62.8	35.45	10.9	0.31	1.14	1.11	750
Artova	18.3	46.6	29.82	7.06	0.24	0.57	0.01	1200
Çamlıbel	18.5	33.6	25.07	4.84	0.19	0.29	-0.91	1100
Sulusaray	18.5	60.5	28.2	8.19	0.29	2.28	8.36	950
Reşadiye	19	46	29.72	7.42	0.25	0.95	0.5	450
Ekinli	17	57.6	31.21	8.6	0.28	1.03	1.9	1070
Zreşadiye	21	60	30.9	8.54	0.28	1.64	3.78	790
Doğanyurt	26.6	59	37.98	8.21	0.22	0.87	0.37	530
Bereketli	21.9	55.1	31.7	9.3	0.29	0.97	-0.07	1125
Hacıpazarı	18.8	84	37.45	16.16	0.43	1.25	1.65	220

STDEV: Standard Deviation; CV: Coefficient of Variation; CS: Coefficient of Skewness

CK: Coefficient of Kurtosis

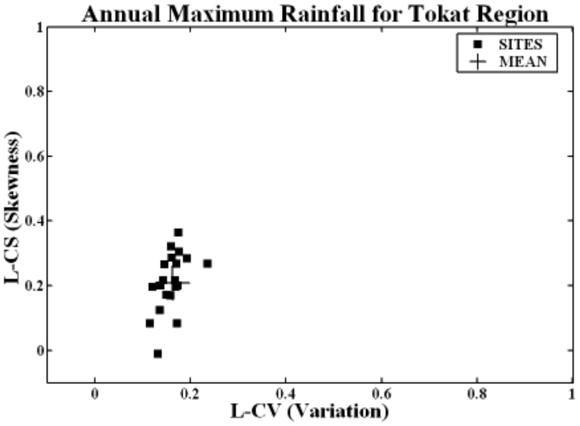

Figure 2. LC_V-LCs moment ratio diagram for annual maximum rainfall for 20 stations in Tokat Region

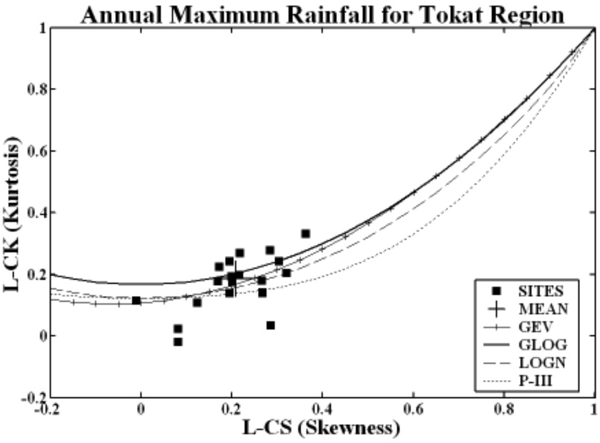

Figure 3. LCs-LCk moment ratio diagram for annual maximum rainfall for 20 stations in Tokat Region

From this table, it is clear that there is no discordant station in both groups as the discordancy measure is smaller than 3 for all stations. The homogeneity measures (H_1, H_2 and H_3) for these two groups are -1.4, -0.74 and -0.75 for the first and 1.43, -1.48 and -1.54. As Rao and Hamed [25] suggest, our judgement on the homogeneity of the groups is limited to H_1 only. Based on the first homogeneity measure, the first group is homogeneous while the second group is not. As the second group is not homogeneous, we try another grouping scenario which divides the region into 3 groups.

Three Groups

Here again, the basis for dividing the region into 3 group is the nearest values of L-moments diagram. The L-moments and discordancy measures of the stations in each group have presented in table 3. According to discrdancy measure, D_i, there is no discordant station in the rainfall groups.

To check the homogeneity of the groups, the homogeneity measure, H_1, was then calculated. The homogeneity measure is -1.22, -0.5 and 0.37 for the first, second and third group, respectively. As all these values are less than H_1=1, we can try to determine the best regional frequency distribution for each region in the next step.

Goodness-of-Fit-Test

The goodness-of fit-test measures, Z^{DIST}, [30] was calculated using the FORTRAN computer program developed by Hosking [33] and presented in Table 4 for Generalized Logistic (GLOG), Generalized Extreme Values (GEV), 3-parameter Log Normal (LN3), Pearson type 3 (P3) and Generalized Pareto distributions.

From this table, we can see that Generalized Extreme Values and Generalized Logistic distributions are the best regional frequency distributions for annual maximum rainfall in three groups, respectively. It should also be noted that for groups 1 and 3, there are also other distributions that could be

Table 2. L-moments and discodancy measures (Di) for two groups

Stations	Sample Size	L-CV	L-CS	L-CK	D_i
Group 1					
Tokat	63	0.17	0.19	0.19	0.16
Zile	63	0.17	0.19	0.24	0.45
Turhal	45	0.16	0.17	0.17	0.13
Erbaa	47	0.17	0.30	0.24	0.26
Niksar	56	0.16	0.21	0.19	0
Boztepe	19	0.17	0.08	-0.02	2.54
Pazar	20	0.17	0.36	0.33	0.84
Çamiçi	12	0.15	0.32	0.20	1.91
Almus Dam	35	0.19	0.28	0.27	1.38
Dökmetepe	34	0.13	-0.01	0.11	2.33
Group 2					
Almus	16	0.17	0.26	0.13	0.31
Artova	22	0.13	0.12	0.10	0.64
Çamlıbel	11	0.11	0.08	0.02	1.84
Sulusaray	28	0.14	0.21	0.2672	1.06
Reşadiye	24	0.13	0.20	0.17	0.14
Ekinli	30	0.15	0.17	0.22	0.71
Zreşadiye	28	0.14	0.26	0.17	0.62
Doğanyurt	25	0.12	0.19	0.13	0.38
Bereketli	25	0.16	0.28	0.03	1.74
Hacıpazarı	23	0.23	0.26	0.14	2.55

Table 3. L-moments and discodancy measures (Di) for three groups

SITE	Sample Size	L-CV	L-CS	L-CK	Di
Group 1					
Boztepe	19	0.17	0.08	-0.02	1.28
Dökmetepe	34	0.13	-0.01	0.11	1.25
Artova	22	0.13	0.12	0.10	0.21
Çamlıbel	11	0.11	0.08	0.02	1.32
Doğanyurt	25	0.12	0.19	0.13	0.93
Group 2					
Tokat	63	0.17	0.19	0.19	0.64
Zile	63	0.16	0.19	0.24	0.74
Turhal	45	0.15	0.17	0.17	0.85
Niksar	56	0.16	0.21	0.19	0.87
Sulusaray	28	0.14	0.21	0.26	1.5
Reşadiye	24	0.13	0.20	0.17	1.46
Ekinli	30	0.15	0.17	0.22	0.94
Group 3					
Erbaa	47	0.176	0.30	0.24	0.11
Pazar	20	0.17	0.36	0.33	1.61
Çamiçi	12	0.15	0.32	0.20	0.39
Almus Dam	35	0.19	0.2847	0.27	0.85
Almus	16	0.17	0.2673	0.13	0.31
Zreşadiye	28	0.14	0.2659	0.17	1.23
Bereketli	25	0.16	0.2861	0.03	1.6
Hacıpazarı	23	0.23	0.26	0.14	1.91

Table 4. Goodness-of-Fit-Test measures (Z^{dist}) for Tokat region

Region	GLOG	GEV	LN3	P3	GPAR
Tokat Region	0.66*	-1.18*	-1.67	-2.65	-5.42
Group 1	2.96	1.32*	1.50*	1.37*	-1.91
Group 2	-0.95*	-2.27	-2.55	-3.17	-5.27
Group 3	0.71*	0.01*	-0.52*	-1.41*	-1.87

*** The distribution may be accepted as a regional distribution**

candidate for regional distribution but we consider one with the smallest $\left|Z^{dist}\right|$.

CONCLUSIONS

The estimation of annual maximum rainfall in a region where no data is available is very important for engineering hydrologic design. The method of L-moment was used for regionalization of annual maximum rainfall in Tokat region. It was showed that the annual maximum rainfall depths do not change with the elevation of the stations. Thus, the regionalization of annual maximum rainfall could not be done based on physical characteristics of the rainfall. The method of L-moment is therefore suitable to fins regional statistics and quantiles of annual maximum rainfall in the region. The use of moment ratio diagram to find initial groups seemed suitable in this study as it was also shown by Vogel and Fennessey [29] and Modarres [19] for low flows and annual rainfall, respectively. This study also showed that Generalized Extreme Values and Generalized Logistic distribution were found suitable for regional annual maximum rainfall frequency analysis. In general, the use of L-moment method is suggested to find homogeneous regions based on annual maximum rainfall in the country.

REFERENCES

[1]. Smithers JC, Schulze RE. 2001. A methodology for the estimation of short duration design storms in South Africa using a regional approach based on L-moments. Journal of Hydrology. 241: 42-52.

[2]. Schaefer MG. 1990. Regional analyses of precipitation annual maxima in Washington State. Water Resources Research. 26: 119–131.

[3]. Nandakumar N. 1995. Estimation of extreme rainfalls for Victoria— application of the Forge method. Working Document 95/7, Cooperative Research Centre for Catchment Hydrology. Monash University, Clayton, Victoria, Australia.

[4]. Nadarajah S. 2005. Extremes of daily rainfall in West central Florida. Climatic Change. 69: 325–342.

[5]. Stedinger JR., Vogel RM, Foufoula-Georgiou E. 1993. Frequency Analysis of Extreme Events. Handbook of Hydrology. McGraw-Hill, New York.

[6]. Durrans SR, Kirby J T. 2004. Regionalization of extreme precipitation estimates for the Alabama rainfall atlas. Journal of Hydrology. 295: 101-107.

[7]. Cunnane C. 1989. Statistical distributions for flood frequency analysis. WMO Report No. 718. World Meteorological Organization, Geneva, Switzerland.

[8]. Hosking JRM, Wallis JR. 1997. Regional Frequency Analysis: An Approach Based on L-Moments. Cambridge University Press, Cambridge, UK.

[9]. Pilon PJ, Adamowski K. 1992. The value of regional information to flood frequency analysis using the method of L-moments. Canadian Journal of Civil Engineering. 19 (1): 137–147.

[10]. Lettenmaier DP. 1985. Regionalisation in flood frequency analysis— is it the answer? US–China Bilateral Symposium on the Analysis of Extraordinary Flood Events, Nanjing, China.

[11]. Potter KW. 1987. Research on flood frequency analysis: 1983– 1986. Review of Geophysics. 25 (2): 113–118.

[12]. Greenwood J A, Landwahr J M, Matalas NC, Wallis JR. 1979. Probanility weighted moments: Definition and relation to parameters of several distributions expressible in inverse form. Water Resources Research. 15 (5): 1049-1054.

[13]. Hosking JRM. 1986. The theory of probability weighted moments. Res. Rep. RC 12210, IBM Research Division, Yorktown Heights, NY.

[14]. Hosking JRM. 1990. L-moments: analyzing and estimation of distributions using linear combinations of order statistics. Journal of Royal Statistical Society B, 52: 105-124.

[15]. Guttman NB. 1993, The use of L-moments in the determination of regional precipitation climates. Journal of Climate. 6: 2309-2325.

[16]. Naghavi B, Yu FX. 1995. Regional frequency analysis of extreme precipitation in Louisiana. Journal of Hydraulic Engeenering. 121: 819– 827.

[17]. Smithers JC. 1996. Short-duration rainfall frequency model selection in Southern Africa. Water SA. 22: 211–217.

[18]. Yurekli K. 2005. Regional analysis of monthly rainfalls over Amasya province via l-moments method. Journal of The Agricultural Faculty of Gaziosmanpasa University. 22 (2): 51-56.

[19]. Modarres R. 2006. Regional precipitation climates of Iran. Journal of Hydrology (NZ). 45: 13-27.

[20]. Yurekli K. 1999. Hydrologic Characteristics of Amasya ve Tokat Provinces. PhD. Thesis (Unpublished), Department of Agriculture Technology, Faculty of Agriculture, University of Ankara, Ankara, Turkey, (In Turkish).

[21]. Topaloğlu F. (2002). Determining suitable probability distribution models for flow and precipitation series of the Seyhan river basin. Turkish Journal of Agriculture and Forestry, TUBITAK. 26: 187-194.

[22]. Okman C. 1983. Determination of duration curves of monthly rainfalls of Ankara province. Technical journal of Topraksu. 61: 22-30, (In Turkish).

[23]. Balaban A, Sen E, Okman C. 1976. Determination of the daily maximum rainfall frequencies in Urfa region. University of Ankara, Agriculture Faculty Year-Book. 26: 761-779, (In Turkish).

[24]. Okman C. 1975. Determining reoccurrence probability of the maximum daily rainfalls that create a surface drainage problem in Cubuk Creek watershed. Assoc. Prof. Thesis (Unpublished), Faculty of Agriculture, University of Ankara, Ankara, Turkey, (In Turkish).

[25]. Rao AR, Hamed KH. 1997. Regional frequency analysis of Wabash river flood data by L-moments. Journal of Hydrologic Engineering. 2 (4): 169-179.

[26]. Hosking JRM, Wallis JR, Wood EF. 1985. Estimation of the generalized extreme value distribution by the method of probability weighted moments. Technometrics. 27: 251-261.

[27]. Hosking JRM, Wallis JR. 1987. Parameter and quantile estimation for the generalized pareto distribution. Technometrics. 29 (3): 339-349.

[28]. Kroll CK, Vogel RM. 2002. Probability Distribution of low streamflow series in the United States. Journal of Hydrologic Engineering. 7 (2): 137-146.

[29]. Vogel RM, Fennessey NM. 1993. L-moment diagram should replace product moment diagram. Water Resources Research. 29 (6): 1745-1752.

[30]. Hosking JRM, Wallis JR. 1993. Some statistical useful in regional frequency analysis. Water Resources Research. 29 (2): 271-281

[31]. Hosking J R M. 1996. Fortran Routines for use with the method of L-moments, Version 3, Res. Rep. RC 20525, IBM Research Division, York Town Heights, NY.

[32]. Rao AR, Hamed, KH. 2000. Flood Frequency Analysis. CRC Press, Boca Raton, FL.

[33]. Hosking JRM. 1991. Fortran Routines for use with the method of L-moments, Version 2, Res. Rep. RC 17097, IBM Research Division, York Town Heights, NY.