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Comparison the application of linear Moment Method with Custom Methods For Estimation of Peak Flood Discharge in Three Selected Stations of North Iran

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Abstract— Two current method for calculating of statistical parameter about flood have been ordinary moments and maximum likelihood. Another new method for computation of this statistical parameters in the recent years,that using in the world have been linear moments that applied for assessment in different area of the world. The aim of this study was to evaluate this method in three selected stations with a length of 30 years in the watershed of Talar of Mazandaran Province, in order to evaluate the efficiency of this new method in this region and, if appropriate, to be used in flood studies in this region. The results of this study indicate that in the three selected stations in the region and with respect to the comparison of three methods of calculating statistical parameters used in peak flood discharge including Ordinary moment method, maximum likelihood method and linear moment method, in some stations linear moment method has higher accuracy from the previous custom methods that shows it is necessary to study this method for further flood studies.

Keywords — Statistical Parameters, Flood, Linear Moment,Gumble Distribution,Talar Watershed

I. INTRODUCTION

Extreme rainfall events and the resulting floods can take thousands of lives and cause billions of dollars in damage. Rood plain management and designs for flood control , reservoirs, bridges, and other investigations need to reflect the likelihood or probability of such events. Hydrologic studies also need to address the impact of unusually low stream flows and pollutant loadings because of their effects on water quality and water supplies. Rainfall and floods can cause accidents resulting in thousands of deaths and millions of dollars are due. Flood management and design for flood control, dams, bridges, and other research needed to reflect the likelihood or likelihood of any event occurring. Hydrological studies are also needed to find the unusual effects of minimum river flows and sediment contamination in order to have an impact on water quality and extraction. Frequency analysis is an information problem: if one had a sufficiently long record of flood flows, rainfall, low flows, or pollutant loadings, then. Frequency distribution for a site could be precisely determined, so long as change over time due to urbanization or natural processes did not alter the relationships of concern. In most situations, available data are insufficient to precisely define the risk or large floods, rainfall, pollutant loadings, or low flows. This forces hydrologists to practical knowledge of the processes involved, and efficient and robust statistical techniques, to develop the best estimates of risk that they can. The hydrologist should be aware that in practice the true probability distributions of the phenomena in question are not known. Even if they were, their functional representation would likely have too many parameters to be of much practical use. The practical issue is how to select a reasonable and simple distribution to describe the phenomenon of interest, to estimate that distribution's parameters, and thus to obtain risk estimates of satisfactory accuracy for the problem at hand. In other instances the risk may be attributable to more than one factor. flood risk at a site may be due to different kinds of events which occur in different season so reduce to risk from several sources of flooding or coincident events, such as both local tributary floods and large regional floods which result in backwater flooding from a reservoir or major river. When the magnitudes of different factors are independent, a mixture model can be used to estimate the combined risk[27]. The science of hydrology, using statistics and probabilities, tries to minimize such damage by following the laws of nature. Hydraulic designs usually address several aspects, including the economic justification, efficiency and utilization of the hydro project. Structural and related engineers try to make the water structure as robust, reliable and inexpensive as possible, and hydrology experts justify the size or grandeur of the structure, the confidence factor against destructive events, such as flood and economic justification and project life. Today, with the use of statistics, human beings have contributed to the robustness and assurance of the healthy exploitation of water projects [19]. To calculate maximum, minimum, and average discharges with different return periods, they use specific statistical distributions (such as normal, two-parameter normal log, three-parameter normal log, Pearson type III, Pearson type III, and Gamble).Also, specific methods such as (maximum likelihood, graphical method, empirical formulas, moment method) are used to estimate statistical parameters of each of these distributions (including mean, standard deviation, skewness and elongation) in this study to estimate statistical parameters. The L-moment method was used. The L-moment method with linear statistical distribution function is one of the new methods used to select appropriate statistical distributions for hydrological and meteorological data. Statistical parameters obtained by L-moment method can be used to calculate maximum, minimum and average discharges with different return periods from different statistical distributions and finally, by using fitting tests, the best distribution for different stations is obtained. Finally, the efficiency of this method can be compared with the custom moment method and maximum likelihood, which are the main objectives of this study.

II. RELATED WORK

Many innovations in the field of flood frequency analysis have occurred since the decision of the U.S. Water Resources Council [10] to recommend the use of the log Pearson type 3 (LP3) distribution for flood-flow investigations in the United States. The state of the art of selecting a regional flood frequency distribution at the time of the LP3 mandate was considerably different from the current situation. For example, in describing the U.S. Water Resource Council (WRC) work group study.. Benson[10,2] argued that "no single method of testing [alternative hypotheses] was acceptable to all those on the Work Group, and the statistical consultants could not offer a mathematically rigorous method," leading to the conclusion that "there are no rigorous statistical criteria on which to base a choice of method." More recently, L-moment diagrams and associated goodness-of-fit procedures[12,34,4,13,3,32,33] were advocated for evaluating the suitability of selecting various distributional alternatives in a region. For example, Hosking and Wallis [12] found L-moment diagrams useful for selecting the generalized extreme value distribution (GEV) over the Gamma distribution for modelling annual maximum hourly rainfall data. Similarly, Wallis[34]found an L moment diagram useful for rejecting Jain and Singh's[16] conclusion that annual maximum flood flows at 44 sites were well approximated by a Gumbel fit of alternate probability models and associated parameter estimation schemes is nonparametric experiments of the type performed by Beard[1] and summarized by the Interagency Advisory Committee on Water Data (IACWD) [11]. Using 300 stations distributed across the United States, Beard counted the number of stations for which the estimated 1,000-yr flood flow was exceeded in the historical record. Eight independent methods were employed for estimating the 1,000-yr flood at each site; results are reproduced in Table 1 distribution and for suggesting a GEV distribution instead. Another approach for evaluating the Beard argued that with a total of n = 14,200 station years of data across the 300 sites, one would expect approximately 14 exceedances of the true 1,000-yr flood flow.

TABLE 1. Number of Stations Where One or More Observed Flood Events Exceeds1,000-Yr Flood Flow

Method	Number of excedance
Log Pearson type3(Lp3)	14
Lognormal(LN2)	18
Gumble(MLE estimators)	77
Log Gumble	1
Gamma	68
Pearson type3(p3)	56
Regional log pearson type3	20
Gumble(best linear invariant estimator	253
Note: from Beard[1] (1974) and iacwd["Guidelines" [11]	

Only the LP3 and LN2 distributions came close to reproducing the 14 expected exceedances. Beard [1] performed many other tests, but it was this test that convinced hydrologists that both the LP3 and LN2 models approximate the distribution of observed flood-flow data throughout the entire United States. A third approach to evaluating the fit of alternative probability models to a regional data base is to employ probability plots and associated probability plot correlation coefficient (PPCC) tests[29,30,31,3]. Such tests are useful., simple, and powerful for most two-parameter distributional alternatives, [29,30,]. Cunnane[4] summarizes the results of a worldwide survey of flood frequency methods prepared for the World Meteorological Organization in 1984, which is partially reproduced in Table 2. The survey involved 55 agencies from28 countries. Some countries reported use of more than one distribution as a standard. Of the six distributions reported in Table 3, the most common distributions appear to be the Gumbel EVl), two-parameter lognormal (LN2), Pearson Type III(P3), and log-Pearson Type III (LP3) distributions. Only one country uses the GEV distribution in spite of its recent popularity, documented later on.

TABLE 2. Summary of Frequency of Use of Various Probability Distributions [from Cunnane (1989), Appendix 6)

Probability distribution	**Number of agencies in which it is used as a standard**	**Number of countries in which it is used as a standard in one or more agencies**
EVl gumbel	**18**	**10**
EV2 extreme value type 2	**3**	**3**
GEV generalized extreme value	**5**	**1**
LN2 lognormal	**16**	**8**
P3 Pearson Type III	**12**	**10**
LP3 log-Pearson Type III	**17**	**7**

Numerous investigators have applied L-moment diagrams to assess the goodness of fit of various PDs to regional samples of flood flows: [34,20,7,24,22,17,32,26,21]..Even though these studies involve flood flow samples throughout the world (Australia, New Zealand, Canada, the United States, and Bangladesh), all studies recommend the use of the GEV distribution. the recommendations from the remaining six studies are based on relatively small regional samples. Nevertheless, together, the nine studies exploit 944 individual samples of annual maximum flood flows across the globe, including some of the longest records available in the world [21].Apparently L-moment diagrams reveal an emerging consensus regarding the choice of a regional parent PD.This study exploits a much larger regional database in the continental United States (1,490 basins) to evaluate the consistency of this emerging consensus on a regional PD. Among the nine studies, only the two studies by Vogel et al. [32] and Onoz and Bayazit [21] evaluated the goodness of fit of a LP3 distribution. Together, the two studies by Vogel et al [32] exploit 444 basins in the United States and Australia, and indicate that the GEV, LP3, and a three-parameter lognormal (LN3) PD provide equally acceptable models for the distribution of flood flows. Farquarson et al [6] fitted a GEV distribution for the annual flood flow data at 1121 metering stations in 70 different countries using probable weights. Although they did not conceive of a fitting fit for the GEV distribution, they used regional exponential curves that made them comparable across regions. Madsen et al. [18] have also used the project design approach in planning and designing urban systems, inland canals, water infrastructure and flood measurement, and various ecological and environmental studies. Since their introduction to the water resources literature, L-moment diagrams have been used repeatedly to assess the goodness of fit of flood flows; however, to our knowledge, there is one study for annual minimum low flows [23].

III. METHODOLOGY

The study area of the Talar Watershed is located in central Alborz on both sides of Tehran, Ghaemshahr road. The study area is 210088.7 ha which is in the coordinates of 52 35 22/ 2 to 53 23 34 /19 East longitude and 35 44 23/06 To 36 19 1/6 North latitude is located by a main river called Talar which drains south to north. The main river of this watershed has a total length of about 100 km and crosses near the outlet of the watershed with the kasilian River. The highest elevation is at the northwest end of the watershed, the Shalmjar zardin peak at 3910 m and the lowest point at the outlet of the watershed at 215 m above sea level. The lowlands accounted for about 22%, the medium lands about 70.2% and the high lands about 7.8% of the total area. The Talar River, after leaving the watershed, travels about 50 kilometres in the Ghaemshahr-Babol plain and flows into the Caspian Sea. The rainfall regime of the study area is completely Mediterranean. The annual snowfall coefficient of the study area is 21.9%. The highest recorded temperature in the watershed is 46 degrees Celsius in July and the minimum temperature in the study network is -35.6 degrees Celsius in February. According to the Emberger climate model , the region's climate is divided into five climates from cold to temperate to temperate. Figure (1) shows a map of the position of the Talar in Mazandaran Province and Iran [25].

FIGURE (1): MAP OF THE TALAR AREA IN MAZANDARAN PROVINCE AND IRAN

Hydrometric stations in the area:

The climatic data required for this study were obtained from the Regional Water Organization of Mazandaran Province. In order to select suitable stations for the purpose of this study, bar graphs related to annual peak discharge were drawn. Finally, 3 Talar-Shirgah, Talar-Kiacola and Kasylian-Shirgaht stations were selected for the study. Considering the differences in the available statistical years, a 30-year

$$b_0 = m = \frac{1}{n}\sum_{j=1}^{n} x_{(j)} \tag{2}$$

$$b_1 = \sum_{j=1}^{n-1}\left[\frac{n-j}{n(n-1)}\right]x_{(j)} \tag{3}$$

$$b_2 = \sum_{j=1}^{n-2}\left[\frac{(n-j)(n-j-1)}{n(n-1)\,(n-2)}\right]x_{(j)} \tag{4}$$

$$b_3 = \sum_{j=1}^{n-3}\left[\frac{(n-j)(n-j-1)(n-j-2)}{n(n-1)\,(n-2)\,(n-3)}\right]x_{(j)} \tag{5}$$

common period for the three stations from 1982-83 until 2010 -2011 water year was considered.

Table 3: Characteristic of the selected stations for the study

Shirgah	**Kasilian**	**Talar**	**52-53-14**	**36-18-05**	**220**
Kiakola	**Talar**	**Talar**	**34-33-36**	**41-48-52**	**-5**

THE THEORY OF L MOMENTS:

L moments and probability weighted moments (PWMs) are analogous to ordinary moments in that their purpose is to summarize theoretical probability distributions and observed samples. Similar to ordinary product moments, L moments can be also be used for parameter estimation, interval estimation, and hypothesis testing. Although the theory and application of L moments parallel those for conventional moments, L moments have several important advantages. Since sample estimators of L moments are always linear combinations of the ranked observations, they are subject to less bias than ordinary product moments. This is because ordinary product moment estimators such as s and G require squaring and cubing the observations, respectively, which causes them to give greater weight to the observations far from the mean, resulting in substantial bias and variance. Hosking[13] and Stedinger et al [28] provide a summary of the theory and application of L moments. Greenwood et al [9] summarize the theory of PWMs Perhaps the simplest approach to describing L moments is by first defining probability weighted moments because L moments are linear functions of PWMs [9,13] . PWMs may be defined by

$$\beta_r = E\left[x\left[F_x(x)\right]^r\right] \qquad (1)$$

where F x(x) is the cumulative distribution function of X. When r = 0, β0 is the mean stream flow µ . Hence a sample estimate of the first PWM, which we term b0, is given by m . All higher-order PWMs are simply linear combinations of the order statistics X(n) ≤ · · · ≤X(1)·. Nevertheless, unbi-ased estimators are often preferred in goodness of fit evaluations such as L moment diagrams. Unbiased estimators are preferred because they have less bias for estimatingτ3 and τ4, and they are invariant if the data are multiplied by a constant, which is not the case for the biased estimators. Unbiased sample estimates of the PWMs, for any distribution can be computed from:

Where x(j) represents the ordered streamflows with x(1) being the largest observation and x(n) the smallest. The estimators in (5) can be more generally described using

$$b_r = \frac{1}{n}\sum_{j=i}^{n-r}\left[\frac{\begin{matrix} n-j \\ r \end{matrix}}{\begin{matrix} n-j \\ r \end{matrix}}\right]x_{(j)} \qquad (6)$$

For any distribution, the first four L moments are easily computed from the PWMs using:

$$\lambda_1 = \beta_0 \qquad (7)$$

$$\lambda_2 = 2\beta_1 - \beta_0 \qquad (8)$$

$$\lambda_3 = 6\beta_2 - 6\beta_1 + \beta_0 \qquad (9)$$

$$\lambda_4 = 30\beta_3 - 30\beta_2 + 12\beta_1 - \beta_0 \qquad (10)$$

The first four unbiased L moment sample estimators are obtained by substituting the PWM sample estimators br, (5) into the L moment equations in (7). Equations (7)-(10) are special cases of the general recursion

$$\lambda_{r+1} = \sum_{K=0}^{r}\beta_r(-1)^{r-k}\binom{r}{k}\binom{r+k}{k} \qquad (11)$$

A computer program is available for implementing the method of L moments [14]. In the following sections we briefly define L moment ratios, discuss their relationship to conventional moments, and introduce L moment diagrams.

L MOMENT RATIOS AND THE INTERPRETATION OF L MOMENTS

Analogous to the product moment ratios, coefficient of variation $c_v = \sigma / \pi$ skewness λ and kurtosis κ, Hosking defines the L moment ratios:

$$\text{(L–Cv)} = \qquad \tau_2 = \frac{\lambda_2}{\lambda_1} \qquad (12)$$

$$\text{(L-Skewness)=} \qquad \tau_3 = \frac{\lambda_3}{\lambda_2} \qquad (13)$$

$$\text{(L-Kurtosis)=} \qquad \tau_4 = \frac{\lambda_4}{\lambda_2} \qquad (14)$$

Where = 1,….,4 λ_r are the first four L moments and τ_2 , τ_3 and $\tau 4$ are the L coefficient of variation (L-CV), L skewness, and L kurtosis, respectively. The first L moment (λ_1) is equal to the mean streamflow(μ), hence it is a measure of location. Hosking [13] shows that λ_2 , τ3 , and τ4 can be thought of as measures of a distributions scale, skewness, and kurtosis, respectively, analogous to the ordinary momentsσ, λ, and κ, respectively. In this study, ordinary and maximum likelihood methods were used to estimate the parameters of the statistical distribution functions and the results were compared with the L-moment method. Different tests such as chi-square test, Kolmogorov-Smirnov, the least squares are used to select the best frequency distribution for the available data. Among these methods, the least squares method used in this study can be obtained by the following formula. It is more appropriate to have a smaller residual sum of squares.

$$R.S.S = \left[\frac{\sum_{i=1}^{n} \left(Q_{Ei} - Q_i \right)^2}{n-m} \right]^{1/2} \qquad ((15)$$

Here's the formula:
R.S.S : Sum of squares remaining
Q_{Ei} :estimated value of variable
Q_{0i} : Observed value of variable
N: Number of samples

IV. RESULTS AND DISCUSSION

The purpose of this study is to compare the L-moment method with custom and maximum likelihood methods to determine the efficiency of L-Moment method. Therefore, at first Hyfa software (Hydrologic frequency analysis) was used for frequency analysis of selected discharges. The software first calculates the empirical probability of the data in several ways, then calculates the probability of the data occurring for the various statistical distributions and finally uses the least squares and chi-square tests to determine the appropriate statistical distributions. The statistical distribution parameters in this software are calculated by two methods of maximum likelihood and ordinary moments. In this study, the well-known Weibull method was used to calculate the experimental probability of the data, and then the five distributions used in this study were (two-parameter log normal, three-parameter log normal, Pearson type III, log Pearson type III and Gumble were fitted to each station's data and finally, using the least squares test with two methods of ordinary moment and maximum likelihood and so chi-square test for appropriate distribution. In this study, the normal distribution was not computed because the normal distribution is usually in good agreement with L expansions, but was calculated in Hyfa software using normal and maximum likelihood methods. These steps were performed for the three selected stations of maximum peak discharge per year. The results of the least squares test were extracted using ordinary moments and maximum likelihoods in this software to compare with the L moments method. Following these steps, a computer program was written in Quick Basics to estimate the L- moments. The calculation method in this program is to first sort the data of each station in descending order and then calculate the L- moment ratios including b0, b1, b2 and b3 (first , second , third and fourth order sampling measurements of L). Returns and is the same number of data per station and then calculates the moment of the first, second, third, and fourth steps (mean, standard deviation, skewness, and kurtosis, respectively) and then (coefficient of variation L, skewness L, respectively). And calculate the L kurtosis), which is the calculation for the annual maximum peak discharge of all stations and logarithms of Done. Next, the L-moment method was used to select the best frequency distribution using the residual sum of squared method or R.S.S. In order to use this method QE or the estimated L-moment flow for each of the statistical distributions used in this study, a frequency coefficient must be obtained from the specific relations that are given for each distribution used there. Because of the lengthy computation of this method, a computer program was written in EXCEL software, which ultimately calculates the least sum of squares for each station. The results of the statistical parameters of mean, standard deviation and skewness for the three selected stations investigated by Hyfa software and the computer program written for the linear moment method are presented in Table (4). The maximum annual moment in Discharge is given in Table 5.

Table (4): Results of the Mean Statistical Parameters, Standard deviation, Skewness for the three selected Stations for this study

Statistical Parameter **Station Name**	**Mean**			**Standard deviation**			***Skewness***		
	Normal	**Logaritmic**	**Linear moment**	**Normal**	**Logaritmic**	**Linear moment**	**Normal**	**Logaritmic**	***Linear moment***
Talar-Shirgah	78.93	4.27	78.92	Out of range	0.231	19.39	0.42	-0.60	*1.40*
Talar-Kiakola	20.65	5.11	204.65	Out of range	0.43	73.53	1.51	0.07	*24.69*
Shirgah-Kasilian	*55.85*	*3.88*	*56.52*	*Out of range*	*0.34*	*15.3*	*-0.06*	*0.74*	*-0.65*

Table (5): Minimum Residual Sum of Squares (R.S.S) of L-MOMENT Method for Annual Peak Discharge By the best fitted distributions in this study at three selected stations

STATISTICAL PARAMETER	PEARSON TYPE3 DISTRIBUTION	LOG PEARSON TYPE3 DISTRIBUTION	GUMBLE DISTRIBUTION
Station Name			
Talar-Shirgah	19.34	80.86	82.64
Talar-Kiakola	Out of range	Out of range	90.79
Shirgah-Kasilian	14.55	56.01	65.91

V. CONCLUSION

Diagram (1) also shows the comparison between the sum of squares error of linear moment method for the distributions with fitted maximum annual discharge of the selected stations under study. By the study of this diagram it is shown that with respect to the Pearson type3distribution, the Shirgah-Kasilian station has the least sum of squares and the best fits to the maximum flood discharges in the region. In the case of Log-Pearson distribution of the third type, the Shirgah-Kasilian station with the sum of squares of 56.01 has the least sum of squares of error and fits better with the maximum flood discharge data. And in the Gumble distribution, the Shirgah-Kasilian Station has the sum least error and the best fit to the maximum flood discharge data. On the other hand, the Shirgah-Kasilian Station with the Pearson Distribution Type III is the best choice and the selected method. . It should be noted that the distributions of LN2 and LN3 at none of the three stations investigated by linear moment method did not fit well with the maximum flood discharge data.

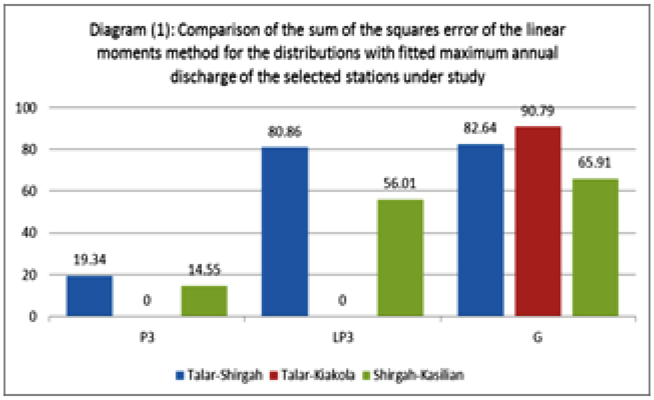
Diagram (1): Comparison of the sum of the squares error of the linear moments method for the distributions with fitted maximum annual discharge of the selected stations under study

In order to better compare the distributions, the best scoring and distribution method has been used. In this comparison, the distribution with the least sum of squares has the highest score and the distribution that has the least sum of the squares with the least score and the distribution that Zero score was not fitted to the data at all. The sum of these scores was obtained for each station and distribution. The distribution with the highest score is the best chosen distribution, the results of which are presented in Diagram (2).

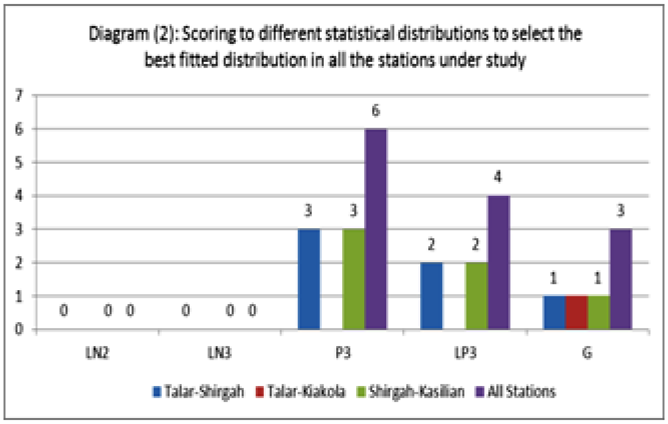
Diagram (2): Scoring to different statistical distributions to select the best fitted distribution in all the stations under study

Selection of appropriate distributions for the selected annual maximum discharge moment

According to the results of this study about the annual maximum moment discharge for the 3 selected stations and comparing the least sum of squares from Table 5 and the sum of the Diagram of the scores given for each distribution (Diagram 2), it is determined that the Pearson type III distribution and L moment method. With a score of 6 with the highest score and the least sum of squares of error, the best method and statistical distribution among the three stations.

This study, Pearson's log type distribution and linear moment method with a score of 4 in the second rank and then Gamble distribution and linear moment method with a score of 3 in the second rank, and the two-variable and three-variable log-normal distributions with Having zero score did not show any good fit with the maximum annual discharge data. This comparison also shows the dominance of the third type Pearson distribution fitting and the linear moment method for calculating the maximum flood discharge for the selected stations. These results are in terms of the dominance of the appropriate distribution for the three stations studied in general, whereas if the issue is investigated in each of the stations separately, it leads to other results such that in the Talar-Shirgah Type III distribution station with Having score 3 was the highest score and best distribution followed by Log Pearson distribution with score 2 and then Gamble distribution with score 1. At Talar-Kiacola Station located in the downstream area of the Talar Watershed, only the Gumble distribution had the rank of 1 and the least sum of squares of error. At the Shirgah –kasillian station, the third type of Pearson distribution has the highest score and the least sum error. After this distribution, the Log-Pearson distribution with the score of 2 and the Gumble distribution with the score of 1, respectively, were placed, respectively they didn't.

Many researchers have worked in a variety of ways on the subject under investigation. For example, Wallis, Hosking [15] introduced uniform tests that are widely used in regional precipitation and flooding, as well as minimal flow, and can be cited by other researchers. Gingas et al[8], using data from the annual floods of 53 hydrometric stations in New Brunswick, Canada and the linear moment method, showed that the data were in accordance with generalized values. Faucher [5] have noted that the estimation quality of the density function improves with increasing sample size. (2004), using linear moments method, investigated the cause of regional and climatic differences of annual runoff in temperate and arid regions of South Africa. Differences in precipitation, vegetation percentage and temperature were the main causes of this difference Announced.

Recommendation:

1 Regarding the positive results of using linear moment method in different parts of the world, it is recommended to be tested in different climates in country in order to evaluate its efficiency in comparison with other methods.

2- In this study, the least squares method is used to select the best statistical distribution. It is recommended that other tests for selection of the best statistical distribution such as Kolmogorov-Smirnov test and Chi-square test be used in other parts of Iran to influence the selection of the best distribution. Statistics to be specified.

3-The length of the statistical period used in this study was a 30-year common statistical period and needs to be studied in other regions with a longer statistical period and with more variations in order to determine its effect on selecting the appropriate distribution.

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