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Frequency Analysis of the Monthly Rainfall Data at Sulaimania Region, Iraq

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Abstract: - Different frequency distributions models were fitted to the monthly rainfall data in Sulaimania region, north Iraq. Three rainfall gauging stations data were used, Sulaimania city, Dokan Dam, and Derbendikhan Dam metrological stations, for the period (1984-2010). The distributions models fitted are of Normal, Log-normal, Wiebull, Exponential and Two parameters Gamma type. The Kolmogorov-Smirnov test was used to evaluate the goodness of fit. The fittings were done for the overall data and for each month separately. The Gamma, Exponential and Weibull distributions were found as the best fits for the three stations respectively for the overall models, while for the monthly models different distribution type was found as the best fit for each month and each station, however the Gamma distributions was found to have the highest percent of best fit. The best fitted distributions were used to forecast three sets of monthly rainfall data for each station and compared to the observed ones for the last 7- years of data. The t-test,F-test and Kolmogorov-Smirnov test indicate the capability of these models to produce data that has the same frequency distribution of the observed one. Comparison between the performances of the overall and periodic models reveals that there no distinguishable improvement of the monthly model over the overall one.

Keywords: - *Frequency Distribution, Kolmogorov-Smirnov test, Sulaimania, Iraq, Rainfall, Forecasting*

I. INTRODUCTION

The complete understanding of the range and the likelihood of rainfall amounts received in a certain location, can provide the designers, planners and decision makers useful guides to prepare for and deal with the consequences of precipitation anomalies. Models of rainfall probability distributions over various timescales can provide useful information. The development of a frequency model starts with the historical data acquisition. These data provide the necessary information about the accumulated rainfall in different locations and describe the time and spatial variability of these rainfall values. The available samples of these historical data should be divided into two sub-samples, the first one should be used for the estimation of the parameters, while the second subsample should be used for verification. When the parameters of the best fitted frequency distribution are estimated and the model is verified, then the model results could be considered dependable and can be used for variety of applications in water resources systems planning and design. Among these applications for example, locating areas of potential hazard precipitation related events, such as draughts and floods, reliability of providing adequate water for rain-irrigation dependent projects, feasibility of the construction of a water harvesting dams, etc. Different probability distributions could be found in literature, such as normal, log-normal, weibull, exponential, Gamma, log-person and others. When the parameters of any distribution are found , then the probability of any event r>ro, where ro is a threshold value selected by the analyzer ,could be found, and hence provide useful information about the most probable events that could occur and plan and design to overcome its consequences. Many researches had been conducted to find the probability distribution function parameters of rainfall data. Husak et al.(2006) , had presented the use of Gamma distribution to reflect the variability of monthly rainfall in Africa. They used the Kolmogorov-Smirnov test for the goodness of fit of weibull and Gamma functions for different locations in Africa. They observed that for 98% of the locations the

Gamma distribution proved the best fit. Sharma and Singh(2010) had used the normal, log-normal, Gamma, Weibull, and Pearson type distributions to fit the daily rainfalls in Pantagar,India. The tests of goodness of fit used are the Kolmogorov-Smirnov, Chi-Square and Anderson-Darlin tests. They concluded that different types of distributions could fit for different locations. Becker (2009) had examined the frequency distributions of the daily precipitation in the United States, using North America regional reanalysis. He observed that the daily precipitation frequencies can be fitted well by the Gamma distribution. Olofintoye et al.(2009) had studied the peak daily rainfall distribution characteristics in Nigeria, by using different frequency distributions such as Gumbel, Log-Gumbel, Normal, Log-Normal, Pearson and Log-Pearson distributions. 20 stations having annual rainfall data of fifty-four (54) years were selected to perform this analysis.. Results showed that the log-Pearson type III distribution performed the best by occupying 50% of the total station number, while Pearson type III performed second best by occupying 40% of the total stations and lastly by log-Gumbel occupying 10% of the total stations. Grifdiths et al. (2009) had used extreme value type I frequency distribution to model rainfall in Christchurch city in Newzealand, they observed that the model predictions of rainfall depths are on average 25% lower than the observed. Prudhomme and Farquharson (2003) had estimated the probability distributions of long period rainfalls and made a drought severity assessment for the UK. Kwaku and Duke (2007), had used the normal, log-normal and gamma frequency distributions to model the maximum daily rainfalls in Accra, Ghana. Results revealed that the log-normal frequency distribution was the best fit for both the one day annual maximum and 2 to 5 days maximum rainfall. Park and Junk (2001) had used the 4-parameters Kappa distribution with the maximum likelihood estimates to model the summer extreme rainfalls in South Korea. Abdullah and AL-Mazroui (1998) had found that the gamma frequency distribution provides the best fit for the annual rainfall in the southwestern region of Saudi Arabia, among the other distributions used ,the normal, log-normal and the exponential distributions.

The Sulaimania Region is one of the important areas in Iraq. Recently continuous developments of water resources projects are under design and planning phases. Due to the reduced surface water that coming from near countries of Turkey and Iran. The water resources authorities try to make use of the runoff water resulted from the rainfall storms falling on the regional territories as an important additional source of water. So many water harvesting dams are planned to be built, for large irrigation projects, hydropower generation, and resettlement of distributed small villages around water resources. These projects planning and feasibility studies are definitely in need of the probable rainfall quantities that could be received in the area. This paper is one of the contributions that could provide future estimation of the probability of rainfall events in this area and its results could be useful for those studies for planners and decision makers of these projects. Hence this area was selected for the present analysis.

The estimation of the probabilities of rainfall values needs the mathematical definition of the probability density function (PDF) of the selected distribution. The mathematical description of these density functions could be found in the literature, and following are only those used in this paper.

1- Normal Distribution:

For a variable x normally distributed the probability density function PDF is given as below:

$$f(x|\sigma,\mu) = \frac{1}{\sigma\sqrt{2\pi}} \; e^{-\frac{(x-\mu)^2}{2\sigma^2}} \qquad (1)$$

Where : μ is the mean value and σ is the standard deviation, called as the Location and Scale parameters of the distribution, respectively.

2- Log-Normal Distribution:

For a variable x that Log(x) is normally distributed the PDF is:

$$f(x|\sigma,\mu) = \frac{1}{x\,\sigma\sqrt{2\pi}} \; e^{-\frac{(logx-\mu)^2}{2\sigma^2}} \qquad (2)$$

Where : μ is the mean value of log(x) and σ is the standard deviation of this variable, called as the Scale and Shape parameters of the distribution, respectively.

3- Exponential Distribution:

For a variable x that distributed exponentially the PDF is:

$$f(x|\mu) = \frac{1}{\mu} \; e^{\frac{x}{\mu}} \qquad (3)$$

Where, μ is the Scale parameter of the distribution.

4- Weibull Distribution:

The PDF of this distribution is given by:

$$\text{f}(x|a,b) = \frac{a}{b^{-a}}\, x^{a-1} \; e^{-(\frac{x}{b})^a} \qquad (4)$$

where: a and b are the Shape and Scale parameters respectively.

5- The Gamma Distribution PDF is:

$$f(x|a,b) = \frac{1}{b^a}\left(\frac{1}{r(a)}\right) x^{a-1} \quad e^{\left(\frac{x}{b}\right)} \qquad (5)$$

where: a and b are the Shape and Scale parameters respectively, and $r(a)$ is the Gamma Function.

The parameters estimation methods of these distributions are well known and could be found in relevant text books. The most used two methods are the moments and the maximum likelihood methods. The parameters were estimated in this paper using the SPSS software , Version 20.

II. MATERIALS AND METHODS

Sulaimania Governorate is located north of Iraq with total area of (17,023 km2) and population 1,350,000, (2009). The city of Sulaimania is located (198) km north east from Kurdistan Regional capital (Erbil) and (385) km north from the Federal Iraqi capital (Baghdad). It is located between (33/43- 20/46) longitudinal parallels, eastwards and 31/36-32/44 latitudinal parallels, westwards. Sulaimania is surrounded by the Azmar Range, Goizja Range and the Qaiwan Range from the north east, Baranan Mountain from the south and the Tasluje Hills from the west. The area has a semi-arid climate with very hot and dry summers and very cold winters. (Barzanji, 2003)

Rainfall data were taken from three meteorological stations (sites) inside and around Sulaimania city, which are Sulimania city, Dokan dam, and Darbandikhan dam meteorological stations. Dokan dam metrological station is locacted (61 km) northeast, and Darbandikhan dam metrological station is located (55 km) south east of Sulaimania city. Dokan dam meteorological station is located (114 km) north east of Darbandikhan dam metrological station .The sites coordinates are given in table (1),(Barzinji ,2003).

The models were applied to the data of the case study described above. The length of record for the the three stations is (27) years, (1984-2010). The data for the first (20), years(1984-2003) were used for models building, while the last 7 years data were used for verification,(2004-2010). It is worth to mention that the data are on monthly basis. Moreover since the analysis includes the rainfall as a variable which has zero values for June, July, August and September, in the selected area of the case study, these months are excluded from the analysis. Hence the model was built for the continuous rainy season period from October to May only.

Table (1) shows the north and East coordinates of the metrological stations selected for analysis and their locations are shown in figure(1).

As mentioned above the data used for estimating the models parameters are those for the 20 years of (1984-2003). The goodness of fit test used in the present analysis is the non-parametric Kolmogorov-Smirnov test, which is as follows:

$$D_n = Max \ |F_n(y) - F(y)| \qquad (6)$$

Where:

$$F_n(y) = \frac{\#(\{i \in \{1,2,.,.,n\}: y_i \le y\})}{n} \qquad (7)$$

$$F(y) = \int_0^y f(x) \ dx \qquad (8)$$

Where

$F_n(y)$ is the empirical cumulative probability of observing a value less than or equal y as shown in equation (7).

F(y) is the theoretical cumulative probability at y estimated by the frequency distribution function f(x), with the estimated parameters. A smaller value of D means a better fit between the observed and theoretical distributions, for a fixed number n of observations. The analysis in this paper was done first for obtaining the frequency best fit models for each station using the whole data series, while then periodic models were obtained, i.e., obtaining the best fitted frequency distribution for the rainfall data for each of the three stations, for each month. The first type models will be called hereafter as the overall models, while the second type models will be called as the periodic models.

III. RESULTS AND DISCUSSION

3-1-Overall Frequency models:

The SPSS software gives the SIG. value of the test which is a test parameter if greater than 0.05 then the null hypothesis that the data fits the used distribution is not rejected, otherwise the distribution tried do not fit the data. As the Kolmogrov-Smirnov test value D decreased SIG increased and hence higher SIG values gives better fitting.

A P-P plot (probability-probability plot or percent-percent plot) is a probability plot for assessing how closely two data sets agree, which plots the two cumulative distribution functions against each other.

Figures (2,3,4,5 and 6) shows the fitting P-P plots of the monthly rainfall data for the three respectively. Those figures are indicative for the best fit distribution to the data of the first 20 years of rainfalls(1984-2003), of the cumulative probabilities. Table (2) shows the parameters estimated for each location and each distribution, and the SIG values of the Kolmogorov-Smirnov test. The shaded values indicate the maximum SIG value for each station which indicates that the best fitted distributions are of Gamma(1.749,0.019) for sulaimania station ,Exp(0.011) for Dokan station and Weibull(80.669,0.973) for Derbendikhan station. Moreover it is shown that for sulaimania station the test results indicates that all the distributions fits the monthly rainfall data accept that of the exponential one since the SIG values area all >0.05 accept for the exponential one it is <0.05, however the most best fitted is that of maximum SIG which is the Gamma distribution. For Dokan station only the Exponential and the Gamma distributions are succeed to fit but with the best for the Exponential since it gives the highest value among the two distributions. For Derbendikhan station three of the distributions can fir the Weibull, exponential and the Gamma with the best as the Weibull for it gives the highest SIG value.

As mentioned above the data available was subdivided into two sub-samples , the 7- years (2004-2010), were left for models verification. For each station three randomly generated series were generated for each station using the best fitted distributions as observed above. Table (3) shows the Kolmogorov-Smirnov independent two samples test results. All of the SIG values shown in this table are > 0.05 which indicates that the generated series are of the same frequency distribution of the observed ones. This indicates that these models are capable of generating data series that are probable to occur in these locations concerning the monthly rainfalls ,and hence can be used by planners ,decision makers and hydrologists for testing there planned or designed project for any possible droughts or flood events, or can use these forecasted data for feasibility studies of any water resources project in the area.

The SIG values listed in the table are all > 0.05 which indicates that the generated series have the same frequency distributions of the observed ones. Table (4) shows the t-test for the significant differences in the means of the observed and generated series of the three station and the three generated series for each station. The results indicates that the t-values are all less than the critical t-value (tc= 1.673), which indicates the acceptance of the null hypothesis of the insignificant differences in the mean values. Similar observations were found for the F-test results as shown in Table(5) where the F-values are all less than the critical F- value(Fc=1.564).

3-2-Periodic Frequency Models:

The process of periodic frequency modeling was done in similar way as for the overall model. The parameters were estimated using the data of the first 20 years (1984-2003), while the verification was done using the second 7 years data (2004-2010). The only difference is that the fittings were made for each month. Table (6) shows the parameters values estimated for each month and each of the 5 frequency distributions used for Sulaimania rainfall station. Table (7) shows the SIG values of the Kolmogorov-Smirnov test for each month and each distribution. All the SIG values are greater than 0.05 which indicates the acceptance of the null hypothesis of insignificant differences in the observed and estimated frequencies. However those distribution with the highest SIG values were selected for the modeling for each month. For October the N(30.165,27.58),Exp(0.033), and Gamma(1.196,0.040) has the same SIG value of 0.56. For November the LN(53.29,1.451) and Gamma(1.371,0.014) distributions has the same SIG value of (0.82), while for the rest months are as shown in Table (7) as a shaded cells.

Table (8) shows the SIG values for three generated series using the best fitted distributions for each month of the Sulaimania station compared with the observed values for the 7 years (2004-2010). Tables (9) and (10) show the T-test and F-test values for the means and variances of the generated and observed series, respectively. The critical t and F values are (1.943, and 4.28) respectively. The results indicate the acceptance of the null hypothesis that the generated and observed series have the same frequency distributions. However for those months that have more than one fitted distribution selected according to the highest SIG values in table (8) , the selection of the proper distribution should be done according to the results of the t-test and F-test shown in tables(9), and (10). Those distributions with relatively low test values should be adopted. Similar analysis were done for the Dokan and Derbendikhan stations as shown in tables (11 to 15) and tables (16 to 20) ,respectively. The summary of the selected proper frequency distribution of the rainfall for each month and each station is shown in table (21).

IV. CONCLUSIONS

The analysis of the overall models conducted in this paper indicates that the monthly rainfall in Sulaimania metrological station can be fitted by the normal,Log-normal,Weibull,and Gamma frequency distributions, however the best one among these is the Gamma(1.749,0.019), since it gives the minimum Kolmogorov-Smirnov test value,i.e. the higest SIG value. For Dokan station the distributions that fits are the

Exponential and Gamma, with the Exponential(0.011) as the best and those for Derbendikhan station are Weibull,Exponential and Gamma distribution with the best fit of Weibul(80.669,0.973),one. The generated sequences of the monthly rainfall are representative of the real events that could be occurred in the three locations since their means and variances have no significant differences from the observed series as tested by the t-test and F-test respectively. Moreover the Kolmogorov-Smirnov test values for the comparison of the frequency distribution of the three generated series with the observed one indicates that those series has the same frequency distributions as the observed ones.

The analysis of the periodic models conducted in this paper indicates that the best fit distribution is different for each month than the other and that the t-test and F-test values should be used in addition to the SIG value of the Kolmogorov-Smirnov test in order to select which is the best. Results indicates that the Gamma distribution is the one that fits the monthly rainfalls in the three locations with the highest percent, 62.5%,50%,and 37.5% for Sulaimania,Dokan,and Derbrndikhan respectively. However the normal distribution gives the same percent for the last station. The minimum number of fits are those of the log-normal distribution followed by the weibull and then by the exponential distribution.

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Table 1 North and east coordinates of the metrological stations selected for analysis.

Metrological station	N	E
Sulaimania	**35° 33' 18"**	**45° 27' 06"**
Dokan	**35° 57' 15"**	**44° 57' 10"**
Derbenikhan	**35° 06' 46"**	**45° 42' 23"**

Fig. 1 The location of the Sulaimania Region in Iraq.

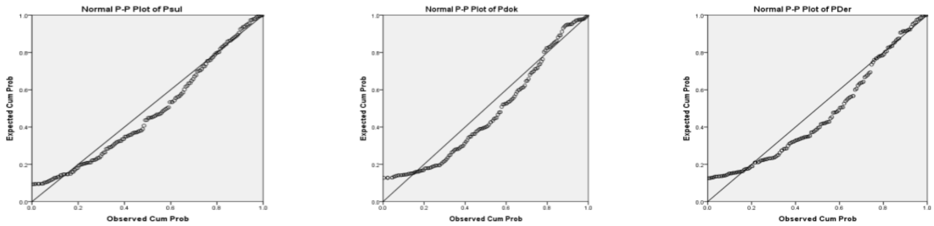

Fig. 2 P-P plots for Normal Distribution Fitting for a) Sulaimania, b) Dokan Dam, c) Derbendikhan Dam, Metrological Stations in Sulaimania Governorate.

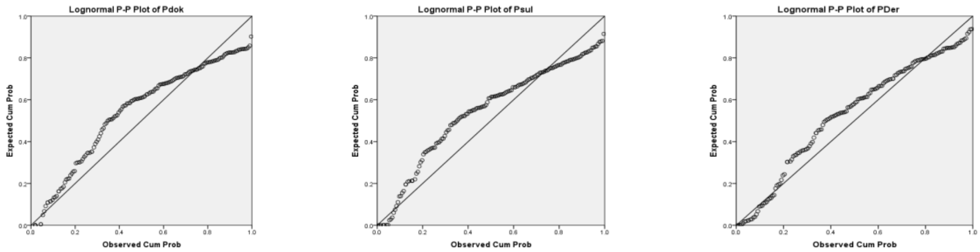

Fig. 3 P-P plots for Log Normal Distribution Fitting for a) Sulaimania, b) Dokan Dam, c) Derbendikhan Dam, Metrological Stations in Sulaimania Governorate.

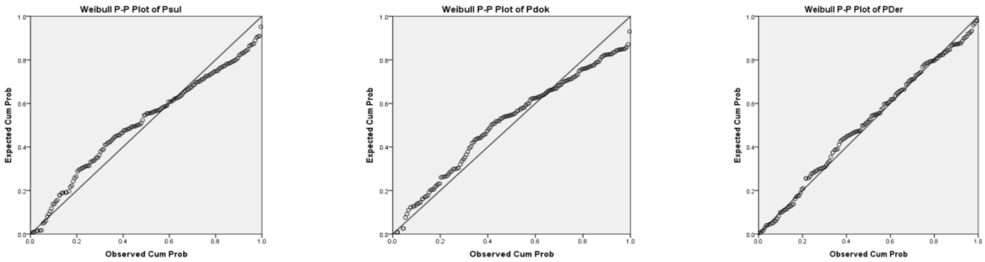

Fig. 4 P-P plots for Weibull Distribution Fitting for a) Sulaimania, b) Dokan Dam, c) Derbendikhan Dam, Metrological Stations in Sulaimania Governorate.

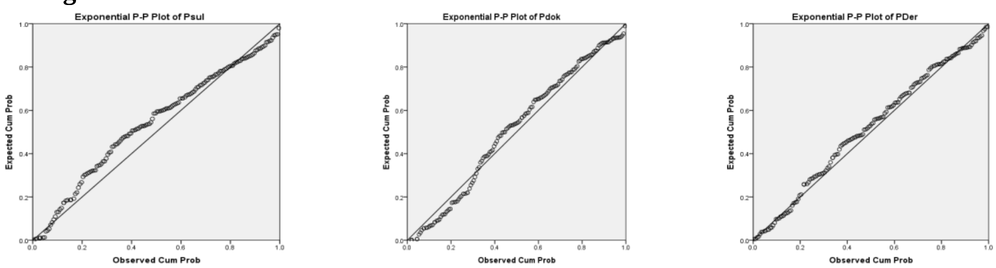

Fig. 5 P-P plots for Exponential Distribution Fitting for a) Sulaimania, b) Dokan Dam, c) Derbendikhan Dam, Metrological Stations in Sulaimania Governorate.

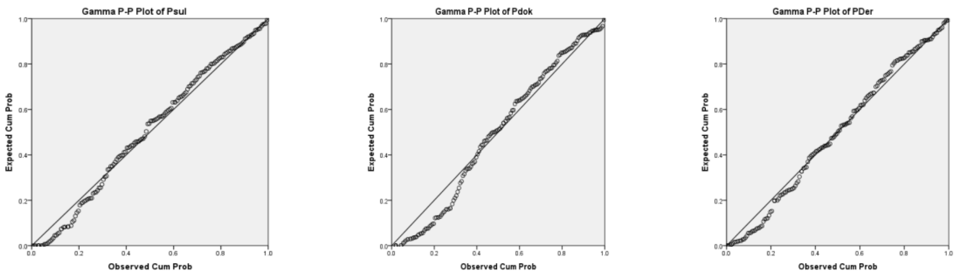

Fig. 6 P-P plots for Gamma Distribution Fitting for a) Sulaimania, b) Dokan Dam, c) Derbendikhan Dam, Metrological Stations in Sulaimania Governorate.

Table 2. Estimated Parameters and SIG values for Kolmogorov-Smirnove Test for the Selected Three Metrological Monthly Rainfall Data at Sulaimania Region, Iraq.

Distribution	Parameters	Sulaimania	Dokan	Derbendikhan
Normal	μ	90.5669	92.1138	77.1056
	σ	68.47393	80.89161	66.9385
	SIG	0.164	0.073	0.073
Log Normal	μ	55.077	44.153	44.795
	σ	1.356	1.734	1.291
	SIG	0.263	0.029	0.021
Weibull	a	0.905	0.687	0.973
	b	103.615	100.37	80.669
	SIG	0.263	0.073	0.913
Exponential	μ	0.011	0.011	0.013
	SIG	0.021	0.263	0.483
Gamma	a	0.019	0.014	0.017
	b	1.749	1.297	1.327
	SIG	0.573	0.209	0.209

Table 3 Kolmogorov-Smirnov Test SIG values for three generated series of the three stations selected in Sulaimania Region using the frequency distribution models and that observed for years(2004-2010).

Generated Series No.	Sulaimania	Dokan	Derbendikhan
1	0.334	0.905	0.979
2	0.617	0.465	0.234
3	0.617	0.617	0.905

Table 4 T- test values for the means of the three generated series of the three stations selected in Sulaimania Region using the frequency distribution models and that observed for years(2004-2010).

Generated Series No.	Sulaimania	Dokan	Derbendikhan
1	0.557	0.209	0.813
2	0.144	0.986	0.828
3	0.674	0.983	0.229

Table 5 F-test values for the variances of the three generated series of the three stations selected in Sulaimania Region using the frequency distribution models and that observed for years(2004-2010).

Generated Series No.	Sulaimania	Dokan	Derbendikhan
1	1.30	1.32	1.52
2	1.15	1.47	1.51
3	1.15	1.50	1.50

Table 6 The Frequency Distribution Estimated Monthly Parameters for Sulaimania Station (1984-2003).

Distrib.	Param.	Oct.	Nov.	Dec.	Jan	Feb	Mar	Apr.	May
Norm.	μ	30.165	98.90	130.55	121.1	105.36	115.73	84.49	37.24
	σ	27.58	84.47	84.65	69.08	53.65	46.24	55.8	27.9
Lnorm.	μ	14.13	53.29	98.65	98.76	93.53	103.104	60.125	19.91
	σ	1.733	1.451	0.956	0.726	0.502	0.565	1.156	1.568
Weibul	a	31.98	103.04	157.33	138.48	118.95	134.89	106.694	42.43
	b	0.671	0.812	1.18	1.63	2.291	2.051	0.962	0.728
Exp.	μ	0.033	0.01	0.008	0.008	0.009	0.009	0.012	0.027
Gamma	a	1.196	1.371	2.378	3.073	3.857	6.264	2.348	1.783
	b	0.04	0.014	0.018	0.025	0.037	0.054	0.027	0.048

Table 7 The SIG Values of the Kolmogorov-Smirnov test for the Best of Fit of the Frequency Distribution Estimated Monthly Parameters for Sulaimania Station ,(1984-2003).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	0.56	0.56	0.82	0.82	0.56	0.172	0.82	0.56
LNorm	0.172	0.82	0.56	0.33	0.82	0.56	0.172	0.82
Weibul	0.33	0.172	0.82	0.82	0.33	0.56	0.172	0.978
Exp.	0.56	0.172	0.56	0.172	0.56	0.172	0.33	0.978
Gamma	0.56	0.82	0.978	0.82	0.978	0.978	0.56	0.82

Table 8. SIG Values for the Kolmogorov-Smirnov Test between the Generated and Observed Rainfalls of Sulaimania station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	0.541	-------	-------	0.541	-------	-------	0.938	-------
	Gen. 2	0.541	-------	-------	0.938	-------	-------	0.938	-------
	Gen. 3	0.541	-------	-------	0.541	-------	-------	0.938	-------
LNorm	Gen. 1	-------	0.541	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	0.541	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	0.541	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	0.938	-------	-------	-------	0.938
	Gen. 2	-------	-------	-------	0.938	-------	-------	-------	0.541
	Gen. 3	-------	-------	-------	0.938	-------	-------	-------	0.541
Exp.	Gen. 1	0.203	-------	-------	-------	-------	-------	-------	0.938
	Gen. 2	0.203	-------	-------	-------	-------	-------	-------	0.541
	Gen. 3	0.203	-------	-------	-------	-------	-------	-------	0.541
Gamma	Gen. 1	0.203	0.938	0.938	0.938	0.938	0.056	-------	-------
	Gen. 2	0.203	0.541	0.203	0.938	0.203	0.056	-------	-------
	Gen. 3	0.203	0.938	0.938	0.938	0.541	0.203	-------	-------

Table 9. T-test Values for the Means of the Generated and Observed Rainfalls of Sulaimania station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	1.453	-------	-------	0.01	-------	-------	0.258	-------
	Gen. 2	0.304	-------	-------	0.29	-------	-------	0.691	-------
	Gen. 3	0.917	-------	-------	0.755	-------	-------	0.174	-------
LNorm	Gen. 1	-------	1.485	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	1.140	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	1.280	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	0427	-------	-------	-------	0.065
	Gen. 2	-------	-------	-------	0.68	-------	-------	-------	1.379
	Gen. 3	-------	-------	-------	0.019	-------	-------	-------	1.179
Exp.	Gen. 1	0.317	-------	-------	-------	-------	-------	-------	1.293
	Gen. 2	0.203	-------	-------	-------	-------	-------	-------	1.485
	Gen. 3	0.520	-------	-------	-------	-------	-------	-------	1.203
Gamma	Gen. 1	0.926	0.410	0.75	0.426	0.973	1.860	-------	-------
	Gen. 2	1.092	0.349	1.85	0.290	1.300	1.153	-------	-------
	Gen. 3	0.254	0.530	0.776	0.555	0.196	1.103	-------	-------

Table 10. F-test Values for the Variances the Generated and Observed Rainfalls of Sulaimania station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	2.72	-------	-------	4.00	-------	-------	1.65	-------
	Gen. 2	2.23	-------	-------	1.13	-------	-------	1.36	-------
	Gen. 3	2.14	-------	-------	2.32	-------	-------	1.88	-------
LNorm	Gen. 1	-------	5.34	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	4.87	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	5.46	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	1.734	-------	-------	-------	2.23
	Gen. 2	-------	-------	-------	1.102	-------	-------	-------	2.18
	Gen. 3	-------	-------	-------	1.636	-------	-------	-------	3.05
Exp.	Gen. 1	2.81	-------	-------	-------	-------	-------	-------	1.57
	Gen. 2	1.18	-------	-------	-------	-------	-------	-------	1.14
	Gen. 3	3.31	-------	-------	-------	-------	-------	-------	1.09
Gamma	Gen. 1	6.33	2.65	2.15	3.20	2.29	1.15	-------	-------
	Gen. 2	9.16	2.13	2.81	1.322	3.17	2.42	-------	-------
	Gen. 3	5.87	1.13	1.98	1.15	1.73	2.45	-------	-------

Table 11 The Frequency Distribution Estimated Monthly Parameters for Dokan (1984-2003).

Distrib.	Param.	Oct.	Nov.	Dec.	Jan	Feb	Mar	Apr.	May
Norm.	μ	27.79	89.285	155.37	128.81	121.715	123.37	72.47	18.10
	σ	33.19	83.05	101.17	76.82	60.25	65.75	64.26	20.64
Lnorm.	μ	5.83	43	113.06	102.19	107.21	101.58	44.93	10.19
	σ	2.85	1.76	1.005	0.78	0.541	0.743	1.312	1.183
Weibul	a	20.61	102.55	182.12	147.05	138.22	144.14	85.54	17.77
	b	0.396	0.634	1.155	1.514	2.168	1.574	0.856	0.991
Exp.	μ	0.036	0.011	0.006	0.008	0.008	0.008	0.014	0.055
Gamma	a	0.701	1.156	3.358	2.812	4.081	3.521	1.272	0.775
	b	0.025	0.013	0.015	0.022	0.034	0.029	0.018	0.043

Table 12 The SIG Values of the Kolmogorov-Smirnov test for the Best of Fit of the Frequency Distribution Estimated Monthly Parameters for Dokan (1984-2003).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	0.172	0.329	0.56	0.978	0.329	0.978	0.56	0.329
LNorm	0.56	0.56	0.978	0.56	0.82	0.329	0.56	0.56
Weibul	0.329	0.329	0.56	0.82	0.329	0.56	0.56	0.56
Exp.	0.56	0.329	0.172	0.82	0.329	0.329	0.82	0.56
Gamma	0.82	0.56	0.56	0.82	0.978	0.56	0.56	0.978

Table 13. SIG Values for the Kolmogorov-Smirnov Test between the Generated and Observed Rainfalls of Dokan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	-------	-------	0.938	-------	0.203	-------	-------
	Gen. 2	-------	-------	-------	0.203	-------	0.541	-------	-------
	Gen. 3	-------	-------	-------	0.203	-------	0.541	-------	-------
LNorm	Gen. 1	-------	-------	0.056	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	0.056	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	0.056	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	0.203	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	0.541	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	0.541	-------
Gamma	Gen. 1	0.203	0.541	-------	-------	0.541	-------	-------	1.00
	Gen. 2	0.541	0.938	-------	-------	0.938	-------	-------	0.203
	Gen. 3	0.938	0.541	-------	-------	0.056	-------	-------	0.541

Table 14. T-test Values for the Means of the Generated and Observed Rainfalls of Dokan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	-------	-------	0.159	-------	0.485	-------	-------
	Gen. 2	-------	-------	-------	0.472	-------	0.194	-------	-------
	Gen. 3	-------	-------	-------	0.529	-------	0.193	-------	-------
LNorm	Gen. 1	-------	-------	0.459	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	0.418	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	0.203	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	0.878	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	0.069	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	0.321	-------
Gamma	Gen. 1	0.105	0.235	-------	-------	0.176	-------	-------	0.585
	Gen. 2	0.430	0.346	-------	-------	0.571	-------	-------	0.240
	Gen. 3	0.254	0.425	-------	-------	0.286	-------	-------	0.542

Table 15. F-test Values for the Variances the Generated and Observed Rainfalls of Dokan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	-------	-------	1.368	-------	2.02	-------	-------
	Gen. 2	-------	-------	-------	2.16	-------	2.01	-------	-------
	Gen. 3	-------	-------	-------	2.29	-------	2.60	-------	-------
LNorm	Gen. 1	-------	-------	2.14	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	2.65	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	1.06	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	2.94	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	2.82	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	2.09	-------
Gamma	Gen. 1	2.81	1.01	-------	-------	1.63	-------	-------	1.33
	Gen. 2	1.12	1.33	-------	-------	1.16	-------	-------	1.01
	Gen. 3	1.13	1.42	-------	-------	1.01	-------	-------	1.21

Table 16 The Frequency Distribution Estimated Monthly Parameters for Derbendikhan (1984-2003).

Distrib.	Param.	Oct.	Nov.	Dec.	Jan	Feb	Mar	Apr.	May
Norm.	μ	27.01	81.39	121.91	104.52	106.52	104.80	50.06	20.65
	σ	27.67	76.12	81.60	68.98	58.33	57.15	32.67	19.39
Lnorm.	μ	14.68	49.296	79.64	82.64	90.75	78.18	37.42	12.82
	σ	1.396	1.152	1.397	0.786	0.606	1.099	0.903	1.056
Weibul	a	28.242	84.21	163.17	119.39	120.51	138.08	56.927	21.25
	b	0.842	1.029	0.768	1.498	1.942	0.969	1.313	1.09
Exp.	μ	0.037	0.012	0.008	0.010	0.009	0.010	0.020	0.048
Gamma	a	0.953	1.143	2.232	2.296	3.334	3.362	2.346	1.134
	b	0.035	0.014	0.018	0.022	0.031	0.032	0.047	0.055

Table 17 The SIG Values of the Kolmogorov-Smirnov test for the Best of Fit of the Frequency Distribution Estimated Monthly Parameters for Derbendikhan (1984-2003).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	0.329	0.978	0.82	0.329	0.82	0.978	0.82	0.56
LNorm	0.172	0.56	0.329	0.172	0.56	0.329	0.56	0.56
Weibul	0.56	0.329	0.56	0.978	0.56	0.172	0.82	0.82
Exp.	0.329	0.56	0.329	0.082	0.56	0.172	0.329	1.00
Gamma	0.82	0.82	0.56	0.978	1.00	0.82	0.978	0.56

Table 18. SIG Values for the Kolmogorov-Smirnov Test between the Generated and Observed Rainfalls of Derbendikhan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	0.938	0.541	-------	-------	0.541	-------	-------
	Gen. 2	-------	0.541	0.056	-------	-------	0.203	-------	-------
	Gen. 3	-------	0.541	0.056	-------	-------	0.203	-------	-------
LNorm	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	0.541	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	0.938	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	0.203	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	-------	0.938
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	1.00
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	0.938
Gamma	Gen. 1	0.203	-------	-------	0.541	0.541	-------	0.203	-------
	Gen. 2	0.056	-------	-------	0.938	0.541	-------	0.938	-------
	Gen. 3	0.541	-------	-------	0.938	0.541	-------	0.541	-------

Table 19. T-test Values for the Means of the Generated and Observed Rainfalls of Derbendikhan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	0.745	1.324	-------	-------	1.031	-------	-------
	Gen. 2	-------	0.608	1.125	-------	-------	1.41	-------	-------
	Gen. 3	-------	0.770	1.965	-------	-------	1.724	-------	-------
LNorm	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	1.06	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	0.21	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	3.09	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	-------	0.34
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	0.077
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	0.412
Gamma	Gen. 1	1.404	-------	-------	1.134	0.522	-------	1.505	-------
	Gen. 2	1.045	-------	-------	0.026	1.02	-------	0.80	-------
	Gen. 3	0.541	-------	-------	0.758	0.566	-------	0.849	-------

Table 20. F-test Values for the Variances the Generated and Observed Rainfalls of Derbendikhan station for (2004-2010).

Dist.	series	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May
Norm.	Gen. 1	-------	1.046	1.85	-------	-------	1.198	-------	-------
	Gen. 2	-------	1.77	1.33	-------	-------	1.41	-------	-------
	Gen. 3	-------	1.525	2.81	-------	-------	1.724	-------	-------
LNorm	Gen. 1	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	-------
Weibull	Gen. 1	-------	-------	-------	1.63	-------	-------	-------	-------
	Gen. 2	-------	-------	-------	1.01	-------	-------	-------	-------
	Gen. 3	-------	-------	-------	2.34	-------	-------	-------	-------
Exp.	Gen. 1	-------	-------	-------	-------	-------	-------	-------	2.15
	Gen. 2	-------	-------	-------	-------	-------	-------	-------	1.42
	Gen. 3	-------	-------	-------	-------	-------	-------	-------	2.47
Gamma	Gen. 1	2.61	-------	-------	2.06	1.65	-------	2.01	-------
	Gen. 2	2.18	-------	-------	1.57	1.22	-------	2.13	-------
	Gen. 3	1.173	-------	-------	2.40	2.01	-------	2.28	-------

Table 21 The Best Fitted Frequency Distributions for the three Selected Stations, Sulaimania, Dokan, and Derbendikhan Monthly Rainfalls.

Model	Sulaimania	Dokan	Derbendikhan
Over all	Gamma(1.749,0.019)	Exp.(0.011)	Weibull.(80.669,0.973)
October	Norm.(30.165,27.58)	Gamma(0.701,0.025)	Gamma(0.953,0.035)
November	Gamma(1.371,0.014)	Gamma(1.156,0.013)	Norm.(81.39,76.12)
December	Gamma(2.378,0.018)	LNorm.(113.06,1.005)	Norm.(121.91,81.6)
January	Weibull(138.48,1.63)	Norm.(128.81,76.82)	Weibull(119.39,1.498)
February	Gamma(3.857,0.037)	Gamma(4.081,0.034)	Gamma(3.334,0.031)
March	Gamma(6.264,0.054)	Norm.(123.37,65.75)	Norm.(104.8,57.15)
April	Norm.(84.49,55.8)	Exp.(0.014)	Gamma(2.346,0.047)
May	Exp.(0.027)	Gamma(0.775,0.043)	Exp.(0.048)