Turkish Journal of Civil Engineering, 2023 167-178, Paper 722, ***Discussion***

Rainfall Intensity-Duration-Frequency Analysis in Turkey, with the Emphasis of Eastern Black Sea Basin†

Discussion by Tefaruk HAKTANIR*

In the paper 672 in Teknik Dergi [1], the authors write: “In this study, only the data of eight standard durations (D=5, 15 and 30 minutes, and 1, 3, 6, 12 and 24 hours) have been employed.” Hence, the data used in the study are shorter than the actually gauged durations of 5, 10, 15, 30 minutes, 1, 2, 3, 4, 5, 6, 8, 12, 18, 24 hours, which are 14 standard durations for annual maximum rainfalls (AMRs) as categorized by the Turkish State Meteorological Service (known by the Turkish acronym MGM). The authors did not give any explanation as to why they excluded those six series. Having skipped six intermediate observed AMRs series in their analyses has been a loss of valuable information. The intensity-duration-frequency (IDF) curves that would have been computed using all of the observed AMRs series of 14 durations would have been more meaningful than the IDF curves that were computed using eight AMRs series. In the publications whose citation numbers in the ‘References’ section of the paper 672 [1] are: [6], [12], [14], [27], [30], which are all related to the IDF relationships for AMRs in Turkey, all of the 14 standard-duration AMRs series from 5 minutes to 24 hours were included. Not having taken into account the actually observed numerical values of the AMRs of the intermediate durations of 10 minutes, 2, 4, 5, 8, 18 hours will cause a loss of real-life information from the results.

In two papers published in SCIE-covered journals, studies closely related to this paper done especially in Turkey are presented, which are listed as publications [2] and [3] in the References section of this Discussion. The authors of the paper 672 [1] overlooked these two papers [2] and [3] summarizing a comprehensive procedure leading to the IDF relationships. In the paper 672 [1], the authors cited four papers published in the journal: *Hydrological Processes* over the years between 2007 through 2020. But, somehow the authors skipped or ignored another relevant paper again in *Hydrological Processes* published in 2010 [2]. Incidentally, Asikoglu and Benzeden in their paper published in *Hydrological Processes* in 2014, which is publication number [30] in the References list of the paper 672 [1], cited these two papers by Haktanır et al (2010) [2] and by Haktanır (2003) [3] and they summarized the procedures presented in them.

In their study, the authors used only three probability distributions, which are: 2-parameter-log-Normal, Gumbel, log-Pearson-type-3. The authors computed the parameters of these

† Ömer YÜKSEK, Tuğçe ANILAN, Fatih SAKA, Emrah ÖRGÜN, Teknik Dergi Volume 34, Issue 4, July 2022. 12087-12103

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three distributions by the method of Moments only. In a relevant report by the World Meteorological Organization (WMO), the probability distributions of Gumbel, 2-parameter-log-Normal (LN2), 3-parameter-log-Normal (LN3), General Extreme Value (GEV), Pearson-3 (P3), log-Pearson-3 (LP3) are recommended for annual extreme rainfalls series [4]. In another relevant report by WMO, the parameter estimation methods of L-Moments and Maximum-Likelihood (ML) are also advocated along with the method of Moments [5]. It is a known fact that the L-Moments method gives exactly the same numerical values for the parameters of a distribution as the method of Probability-Weighted Moments (PWM). In various publications, the parameter estimation methods of ML and PWM are said to have peculiarities superior to the method of Moments on statistical grounds [e.g. 5, 6, 7].

In the paper by Haktanir et al (2010) [2], a statistical model comprising the probability distributions of Gumbel, LN3, P3, LP3, GEV for the frequency analyses of 14 standard-duration annual maximum rainfalls series adopted by MGM, whose ultimate product is the IDF curves, is presented. The reasons for having chosen these five probability distributions for IDF relationships are explained by Haktanir et al (2010) [2] citing quite a few relevant publications in their paper. The model and the resultant computer package presented by Haktanir et al (2010) [2], which has been the outcome of the research project 106Y192 supported by Tübitak (acknowledged in the paper), computes the parameters of each one of Gumbel, LN3, P3, LP3, GEV by each one of the methods of Moments (MOM), PWM, SDPWM, ML. SDPWM stands for "Self-Determined Probability-Weighted Moments" and it is a modified version of the PWM method [8]. A distribution whose parameters are computed by a different method is actually another distribution. The model by Haktanir et al (2010) [2] comprises the probability distributions of Gumbel-MOM, Gumbel-PWM, Gumbel-SDPWM, Gumbel-ML, LN3-MOM, LN3-PWM, LN3-SDPWM, LN3-ML, LN3-SC0, P3-MOM, P3-PWM, P3-SDPWM, P3-ML, LP3-MOM, LP3-PWM, LP3-SDPWM, LP3-ML, GEV-MOM, GEV-PWM, GEV-SDPWM, GEV-ML. LN3-SC0 is another version of the LN3 distribution whose parameters are computed such that the sample skewness coefficient of the normalized variable becomes zero [8]. By these symbols, in paper 672 [1], the distributions of Gumbel-MOM, LN2-MOM, LP3-MOM are used.

Another aspect of the paper 672 [1] is that the authors ignored the scaling of the parameters of those three distributions by not having taken into account their regressions against the rainfall duration. Therefore, the paper 672 [1] ignored the possibility of some of the frequency curves, curves representing the (quantile)↔(probability of exceedence) or equally the (quantile)↔(average return period) relationships, which are known as quantile functions denoted by x(F), of successively-increasing-duration AMRs series to cross each other. Graphically, when the frequency curves of all 14 standard-duration AMRs are drawn in the same graph paper, they should have diverging appearances from each other over all possible ranges of probabilities, meaning over all possible ranges of average return periods (T's) in the interval: $1<T<+\infty$. If each one of 14 frequency analyses of 14 standard-duration AMRs series are done in a straightforward manner ignoring this important constraint, then a frequency curve of a shorter-duration AMR may cross the frequency curve of a longer-duration AMR and extends above it with increasing return periods. This situation is against the rule of conservation of mass, which states that the rainfall depth of a longer-duration AMR must be greater than the rainfall depth of a shorter-duration AMR for the same T. In other words, the magnitude x_2 of a longer-duration AMR, tr_2, must be greater than x_1, of a shorter-duration AMR, tr_1, both having the same average return period, T, which necessitates that the curve of the quantile function of the tr_2-duration AMR must be divergent from that of the tr_1-duration AMR with increasing return periods. Symbolically, for any two rainfall durations such as $tr_2 > tr_1$, x_2(must be)$> x_1$. If these constraints are not satisfied for all of 14 AMRs, then the resultant IDF curves will incorrectly reflect the statistical behavior of AMRs. There have been many publications proposing measures to prevent such absurd cases which are against the principle of conservation of mass. Some of these are publications numbered [2], [3], [10], [11], [12] in the References list of this Discussion.

Instead of scaling the parameters of the probability distributions in terms of logarithms of the rainfall durations, the authors of the discussed paper applied the frequency analyses on each one of those eight standard-duration AMRs in the conventional way. As explained by Burlando and Rosso (1996) [10], Benzeden (2001) [11], Porras and Porras (2001) [12], Haktanır (2003) [3], and Haktanır et al (2010) [2], the statistical characteristics like means, standard deviations, and skewness coefficients of the observed series of the successively-increasing standard-duration AMRs must be scaled by either semi-log or log-log regressions of these characteristics against the rainfall durations from 5 minutes up to 1440 minutes. And next, the parameters of the probability distributions fitted to the successively-increasing standard-duration AMRs must be scaled by again similar regressions against rainfall duration. Apparently, in the paper 672 [1] no such scalings were done, and the numerical values of the original statistics and of the original parameters were used as they were obtained by treating each one of these eight AMRs series (5, 15, 30, 60, 180, 360, 720, 1440 minutes) individually.

With the purpose of demonstrating a more rational way of obtaining the IDF curves at a particular location where MGM has been gauging pluviographic rainfall data with a fairly long record period, we have taken the case of Rize. The paper 672 [1] is somewhat like the summary of the M.Sc. Thesis by E. Örgün, one of the authors of this paper. Having read this thesis, we have understood that the authors used the recorded data of the stations gauged by MGM, and Rize data begin in the year 1940 and the last year of record is 2010. The length of each one of 14 recorded series from 5 minutes to 24 hours is 70 (instead of 71) because the data for the year 1951 are missing in the records. We have already obtained the same data from MGM. First, we typed 14 different input data files whose formats were in accordance with the computer program: FFA11.EXE. This particular code performs single-series frequency analyses comprising eight different probability distributions (including LP3) whose parameters are computed by the methods of MOM, PWM, ML, and a couple of special methods; and, it has been the outcome of related studies over a few decades [e.g. 9, 13, 14, 15]. FFA11.EXE has been used in various research and application studies so far, and it is freely provided to anybody requesting it. The magnitudes of the AMRs of all durations from 5 minutes to 24 hours having average return periods of T = 2, 5, 10, 25, 50, 100, 500 years, as done in the paper 672 [1], were computed by means of FFA11.EXE. The rainfall magnitudes divided by their durations in hours gave the same numerical values presented in Table 9 of the paper 672 [1]. This was a clearcut verification of two aspects: (1) FFA11.EXE performes the frequency analyses by LP3-MOM correctly, and more importantly (2) in the study by the paper 672 [1] the raw parameters were used, namely no scaling was performed.

Aside from the straightforward frequency analyses of 14 standard-duration AMRs series of 70 elements each recorded at Rize, the model by Haktanir et al (20210) [2] was run with the same inputa data of Rize. As mentioned before, this model performs the scaling routine for each one of those 21 probability distributions. Figures 1, 2, 3 here show the plots of both the raw (original) and the scaled sample means, sample standard deviations, and sample skewness coefficients of 14 AMRs series of Rize. We have applied the package program Y.EXE, which has been the outcome of the Tübitak-supported research project 106Y192 [2], to the same AMRs data of Rize. In Figure 4, the frequency curves of AMRs of eight durations (5, 15, 30, 60 minutes, 3, 6, 12, 24 hours) computed by the LP3-MOM distribution with the unscaled parameters for T’s of 2, 5, 10, 25, 50, 100, 500 years are shown; and in Figure 5, the frequency curves of AMRs of all 14 durations (5, 10, 15, 30, 60 minutes, 2, 3, 4, 5, 6, 8, 12, 18, 24 hours) are shown. As seen in Figure 4, the frequency curve of 3-hour-duration AMR goes above the the frequency curve of 6-hour-duration AMR for return periods greater than 200 years. As seen in Figure 5, the congestion of 14 frequency curves of durations greater that 3 hours are more visible. In Figure 6, the frequency curves of AMRs of all 14 durations computed by the LP3-MOM distribution with the scaled parameters again for T’s of 2, 5, 10, 25, 50, 100, 500 years, given by Y.EXE, are shown. As seen in this figure, all of the frequency curves of successively-increasing-duration AMRs are in a diverging order as they should be. Figure 7 shows the IDF curves computed by the LP3-MOM distribution with the unscaled parameters and Figure 8 shows the IDF curves computed by the LP3-MOM distribution with the scaled parameters for the same T’s of 2, 5, 10, 25, 50, 100, 500 years.

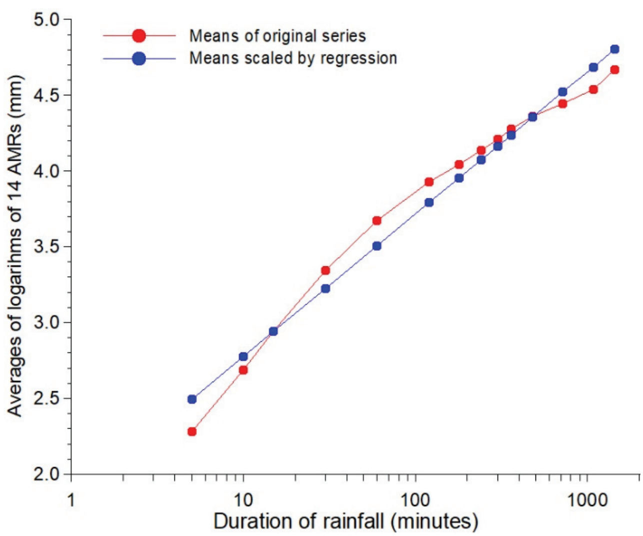

Figure 1 - Plots of (1) means of original series of the 70-year-long data of 14 successively-increasing standard-duration AMRs series of durations of 5, 10, 15, 30, 60 minutes, 2, 3, 4, 5, 6, 8, 12, 18, 24 hours gauged at Rize by MGM over the period of 1940 through 2010 and (2) the means of the same series scaled by regression.

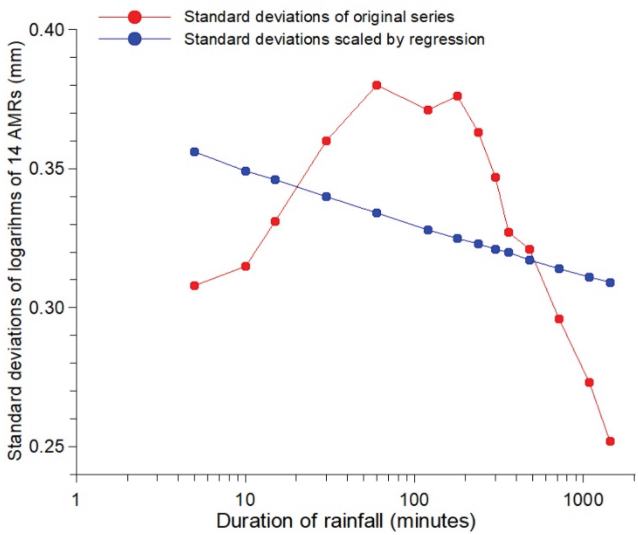

Figure 2 - Plots of (1) the standard deviations of original series of the 70-year-long data of 14 successively-increasing standard-duration AMRs series gauged at Rize by MGM and (2) the standard deviations of the same series scaled by regression.

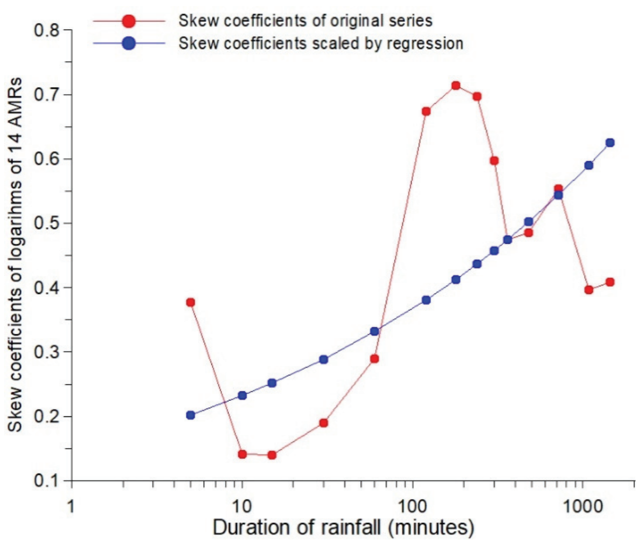

Figure 3 - Plots of (1) the skew coefficients of original series of the 70-year-long data of 14 successively-increasing standard-duration AMRs series gauged at Rize by MGM and (2) the skew coefficients of the same series scaled by regression.

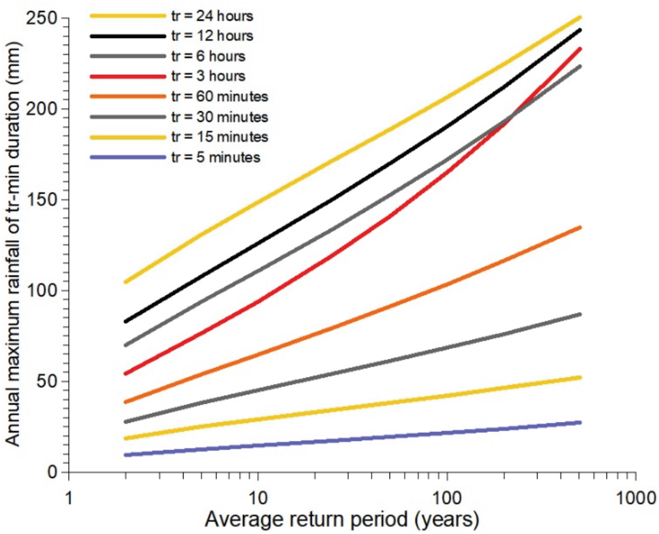

Figure 4 - Frequency curves computed by the log-Pearson-3 distribution with unscaled (raw) parameters computed by the method of Moments using the 70-year-long data of eight standard-duration AMRs series of durations of 5, 15, 30 minutes, 1, 3, 6, 12, 24 hours gauged at Rize by MGM.

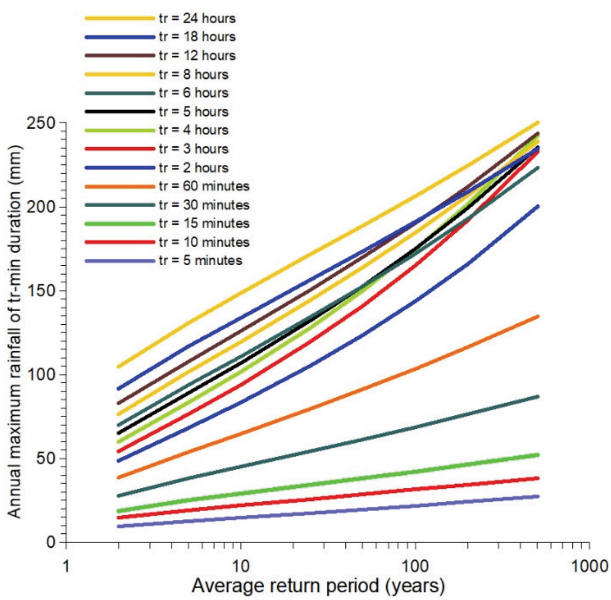

Figure 5 - Frequency curves computed by the log-Pearson-3 distribution with the unscaled (raw) parameters computed by the method of Moments using the 70-year-long data of 14 standard-duration AMRs series gauged at Rize by MGM.

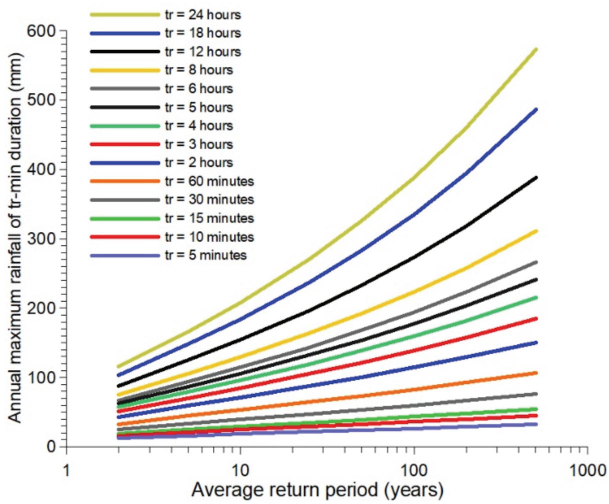

Figure 6 - Frequency curves computed by the log-Pearson-3 distribution with the scaled parameters computed by the method of Moments using the 70-year-long data of 14 standard-duration AMRs series gauged at Rize by MGM.

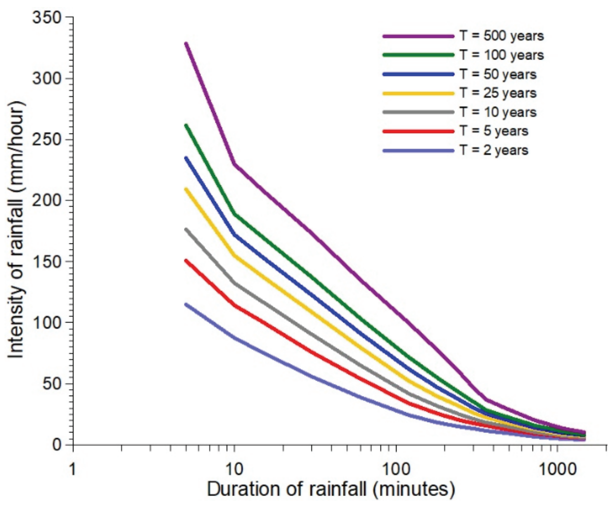

Figure 7 - Intensity-duration-frequency curves for Rize computed by the log-Pearson-3 distribution with the unscaled (raw) parameters by the method of Moments using the 70-year-long data of 14 AMRs series gauged at Rize by MGM.

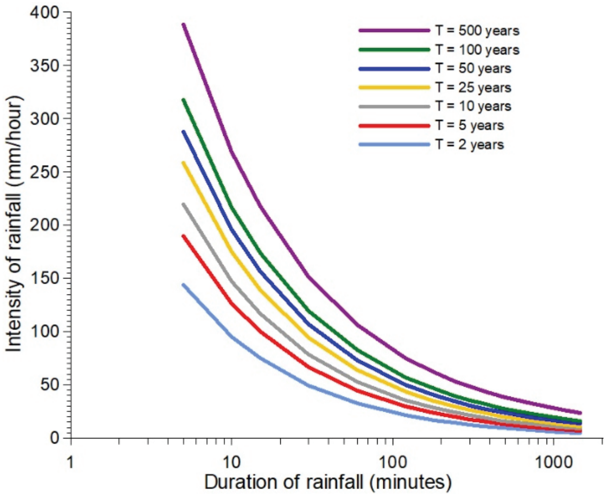

Figure 8 - Intensity-duration-frequency curves for Rize computed by the log-Pearson-3 distribution with the scaled parameters by the method of Moments using the 70-year-long data of 14 AMRs series gauged at Rize by MGM.

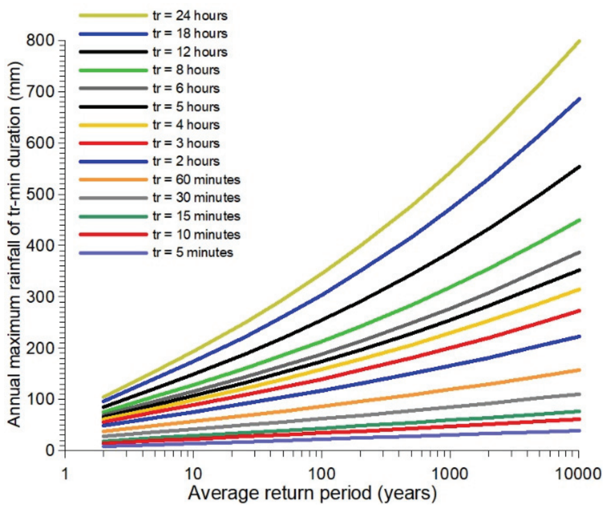

Figure 9 - Frequency curves computed by the log-Normal-3 distribution with the scaled parameters computed by the method of Probability-Weighted Moments using the 70-year-long data of 14 AMRs series gauged at Rize by MGM.

The authors of the paper 672 [1] chose the best-fit distribution among the probability distributions of Gumbel-MOM, LN2-MOM, LP3-MOM based on the goodness-of-fit tests of Chi-square and probability-plot-correlation-coefficient (PPCC). These two tests are widely used for determining the better-fitting distribution, indeed. The model by Haktanir et al (2010) [2] also applies these two goodness-of-fit tests plus another commonly used test of Kolmogorov-Smirnov and it lists so many distributions from the best-fitting down to the worst-fitting giving them numbers as the sum of goodness numbers of the three tests of Chi-square, PPCC, Kolmogorov-Smirnov. Both the source listing and the EXE forms of this computer package will be made freely available to anybody asking for them. According to the conjunctive result of these three tests, the distribution of LN3-PWM with the scaled parameters turned out to be the best-fit one among 21 distributions for the 14 standard-duration AMRs series of 70 elements each of Rize. In Figure 9, the frequency curves of AMRs of all 14 durations computed by the LN3-PWM distribution with the scaled parameters for so many T's from 2 up to 10,000 years, given by Y.EXE, are shown. The upper limit of T is purposely taken to be such a long period in order to verify that the frequency curves are in a diverging formation as they should be. And, in Figure 10, the IDF curves computed using these frequency curves by LN3-PWM for T's between 2 and 500 years are shown. Such IDF figures are automatically drawn by the computer package developed by Haktanir et al (2010) [2] with various options for the upper limits of T between 100 years and 10,000 years in compliance with the choice of the user of the program. In forming Figure 10, we opted for 500 years for the upper limit.

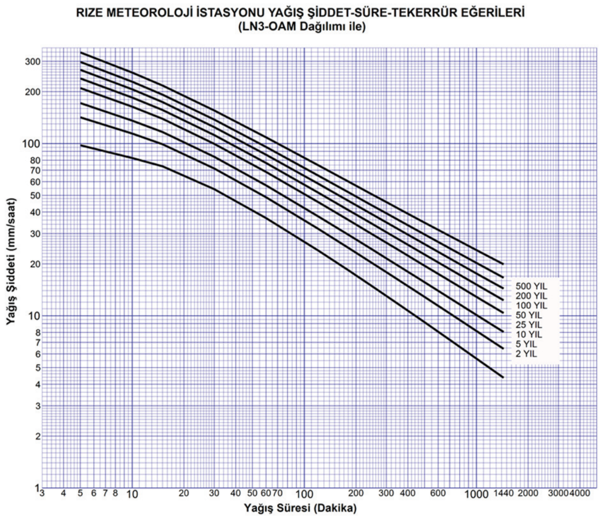

Figure 10 - Intensity-duration-frequency curves given by the computer package by Haktanır et al (2010) [2] computed by the log-Normal-3 distribution with the scaled parameters by the method of Probability-Weighted Moments using the 70-year-long data of 14 AMRs series gauged at Rize by MGM.

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Authors' Closure

First of all, the Authors are grateful to Mr. Haktanır for His priceless discussion. In the following, the discussion and Authors' replies are presented:

Discussion:

In the paper 672 in Teknik Dergi [1], the authors write: "In this study, only the data of eight standard durations (D=5, 15 and 30 minutes, and 1, 3, 6, 12 and 24 hours) have been employed." Hence, the data used in the study are shorter than the actually gauged durations of 5, 10, 15, 30 minutes, 1, 2, 3, 4, 5, 6, 8, 12, 18, 24 hours, which are 14 standard durations for annual maximum rainfalls (AMRs) as categorized by the Turkish State Meteorological Service (known by the Turkish acronym MGM). The authors did not give any explanation as to why they excluded those six series. Having skipped six intermediate observed AMRs series in their analyses has been a loss of valuable information. The intensity-duration-frequency (IDF) curves that would have been computed using all of the observed AMRs series of 14 durations would have been more meaningful than the IDF curves that were computed using eight AMRs series. In the publications whose citation numbers in the 'References' section of the paper 672 [1] are: [6], [12], [14], [27], [30], which are all related to the IDF relationships for AMRs in Turkey, all of the 14 standard-duration AMRs series from 5 minutes to 24 hours were included. Not having taken into account the actually observed numerical values of the AMRs of the intermediate durations of 10 minutes, 2, 4, 5, 8, 18 hours will cause a loss of real-life information from the results.

Reply:

Of course, this is a right discussion. However, it has been concluded that, only the data of eight standard durations (D=5, 15 and 30 minutes, and 1, 3, 6, 12 and 24 hours) are sufficient for this kind of an analysis. However, it is obvious that, the use of data of all of the standard durations will enhance the quality of analysis.

Discussion:

In two papers published in SCIE-covered journals, studies closely related to this paper done especially in Turkey are presented, which are listed as publications [2] and [3] in the References section of this Discussion. The authors of the paper 672 [1] overlooked these two papers [2] and [3] summarizing a comprehensive procedure leading to the IDF relationships.In the paper 672 [1], the authors cited four papers published in the journal: Hydrological Processes over the years between 2007 through 2020. But, somehow the authors skipped or ignored another relevant paper again in Hydrological Processes published in 2010 [2]. Incidentally, Asikoglu and Benzeden in their paper published in Hydrological Processes in 2014, which is publication number [30] in the References list of the paper 672 [1], cited these two papers by Haktanır et al (2010) [2] and by Haktanır (2003) [3] and they summarized the procedures presented in them.

Reply:

The Authors have cited and have not overlooked or made little of these two papers. However, because of the limitations about the length of the paper (for sake of making the paper short to be published), no detailed analysis is given about these papers. Moreover, it is certain that, the aforementioned other papers are very important.

Discussion:

In their study, the authors used only three probability distributions, which are: 2-parameter-log-Normal, Gumbel, log-Pearson-type-3. The authors computed the parameters of these three distributions by the method of Moments only. In a relevant report by the World Meteorological Organization (WMO), the probability distributions of Gumbel, 2-parameter-log-Normal (LN2), 3-parameter-log-Normal (LN3), General Extreme Value (GEV),Pearson-3 (P3), log-Pearson-3 (LP3) are recommended for annual extreme rainfalls series [4].

Reply:

A reply to this discussion has been presented in the paper as: "There are several statistical distributions that might be suitable for rainfall intensity-frequency (or return period, T=1/F) analysis. One should select a few (say 3 to 5) distributions to test the best fit distribution. Various studies have favored the use of three suitable distributions for annual maximum precipitation (and also flood) data in Turkey: Log-Normal Distribution (LN2), Gumbel Distribution (GM) and Log-Pearson Type 3 Distribution (LPT3) [17,25]. Therefore, in this study, these three distributions were tested" (in 3.1. Obtaining IDF Values).

Discussion:

The authors computed the parameters of these three distributions by the method of Moments only. In another relevant report by WMO, the parameter estimation methods of L-Moments and Maximum-Likelihood (ML) are also advocated along with the method of Moments [5]. It is a known fact that the L-Moments method gives exactly the same numerical values for the parameters of a distribution as the method of Probability-Weighted Moments (PWM). In various publications, the parameter estimation methods of ML and PWM are said to have peculiarities superior to the method of Moments on statistical grounds [e.g. 5, 6, 7].

Reply:

The usage of various methods for parameter estimation is, of course, preferable. However, the use of methods of moments is also recommended in various studies and therefore is employed in the paper.

Other Discussions:

The other discussions are mainly related to the scaling of the parameters of the used three distributions and some statistical analyses. These are also right analyses. Of course, there may be similar techniques to be employed in the analysis. However, the Authors believe that their statistical analyses are relevant and enough.

In the end, the use of the computer package by Haktanır et al (2010) may conclude similar, and probably more precise, results.

In short, the discussion has dealt with very important issues, some of which may be used to outperform the study. Despite this fact, the Authors believe that the paper, as it is, has very great significance and has significantly contributed to the literature.