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Bivariate hydrological frequency analysis for the design of hydraulic structures in small Mediterranean watersheds

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Hydrological frequency estimation for the design of hydraulic structures is usually performed as a univariate analysis of flood event magnitudes or rainfall peaks. However, recent studies show that for accurate return period estimation of the extreme hydrological events, the dependence and the correlation pattern among hydrological attribute characteristics, such as peak discharge or rainfall intensity and volume and duration should be taken into account in a multivariate framework and small mountainous watersheds in the Mediterranean. The primary goal of this study is to compare univariate and joint bivariate return periods of floods and extreme precipitation that all rely on different probability concepts in Yermasoyia watershed, Cyprus. Pairs of peak discharge with corresponding flood volumes and extreme daily precipitation with corresponding duration are estimated and compared using annual maximum series (AMS) and peaks over threshold (POT) approaches. The Lyne-Hollick recursive digital filter is applied to separate baseflow from quick flow and to subsequently estimate flood volumes from the quick flow timeseries. Marginal distributions of flood characteristics (peaks and volumes) and extreme precipitation are examined and used for the estimation of typical design periods. The dependence between peak discharges and volumes is then assessed by an exploratory data analysis using K-plots and Chi-plots, and the consistency of their relationship is quantified by Kendall's correlation coefficient. Copulas from Archimedean, Elliptical and Extreme Value families are fitted using a pseudo-likelihood estimation method, evaluated according to the corrected Akaike Information Criterion and verified using both graphical approaches and a goodness-of-fit test based on the Cramér-von Mises statistic. The selected copula functions and the corresponding conditional and joint return periods are calculated and the results are compared with the marginal univariate estimations of each variable. Results indicate the importance of the bivariate analysis in the estimation of design return period.

Keywords: Bivariate analysis, Copulas, Flood Frequency Analysis, Extreme Precipitation, Hydraulic structures, Design return period