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Research Article

Frequency analysis of floods with joint functions, case study: Zayandehrood Dam

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Extended Abstract

Introduction

Floods are among the most significant natural disasters, causing substantial economic and human losses annually. Understanding the frequency and probability of flood events is crucial for effective reservoir management and risk mitigation. Traditional flood frequency analysis often relies on univariate methods, which can be limiting due to the multivariate nature of flood events. Copula functions, which model the dependence structure between variables, offer a more robust approach for multivariate flood frequency analysis. This study focuses on the Zayandeh River Dam in Iran, analyzing 52 years of inflow data to estimate flood return periods using copula functions. The results provide valuable insights for flood risk assessment and reservoir management.

Materials and Method

The study uses 52 years of hydrological data (1971–2022) from the Zayandeh River Dam, located in Isfahan Province, Iran. Three flood variables—peak discharge, flood volume, and flood duration—were extracted from daily hydrographs. The correlation between these variables was assessed using Pearson, Spearman, and Kendall's tau coefficients. Marginal distributions for each variable were fitted using Gaussian, exponential, and Pareto distributions, selected based on goodness-of-fit tests (Kolmogorov-Smirnov, Anderson-Darling, and chi-square). Copula functions from the Archimedean family (Joe and Ali-Mikhail-Haq) were used to model the joint distribution of paired variables. The parameters of the copula functions were estimated using the maximum likelihood method, and the best-fitting copula was selected based on Akaike Information Criterion (AIC), Nash-Sutcliffe Efficiency (NSE), and Root Mean Square Error (RMSE). Univariate and bivariate return periods were calculated and compared.

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Results and Discussion

The statistical analysis revealed a strong positive correlation between flood volume and duration, while peak discharge and flood volume showed negligible correlation. The Gaussian distribution best fit the peak discharge data, while the exponential and Pareto distributions were suitable for flood volume and duration, respectively. The Joe copula was selected for modeling the joint distribution of peak discharge and flood volume, while the Ali-Mikhail-Haq copula was chosen for peak discharge-duration and flood volume-duration pairs. The bivariate return periods, calculated using the selected copulas, provided more reliable estimates compared to univariate return periods. The results demonstrated that extreme flood events, characterized by higher peak discharge, volume, and duration, have longer return periods and lower probabilities of occurrence. The bivariate analysis also highlighted the importance of considering the dependence structure between flood variables for accurate risk assessment.

Conclusion

This study underscores the effectiveness of copula functions in multivariate flood frequency analysis. By modeling the dependence structure between flood variables, copulas provide more accurate estimates of flood return periods compared to traditional univariate methods. The results indicate that bivariate return periods are more reliable for flood risk assessment and reservoir management. The Zayandeh River Dam case study demonstrates the practical application of copula-based analysis in understanding flood behavior and improving flood risk mitigation strategies. Future research should explore the application of copulas in other regions and incorporate additional variables, such as rainfall intensity, to further enhance flood frequency analysis.

Keywords: Conditional probabilities, Bivariate frequency analysis, Copula functions, Bivariate return period, Zayandeh Rood Dam