Journal of Flood Risk Management

WILEY | CIWEM Chartered Institution of Water and Environmental Management

ORIGINAL ARTICLE OPEN ACCESS

Bayesian Analysis of Flood Prediction Using Mixture Models of Weighted Inverse Rayleigh and Gumbel Type-II Distributions

Muhammad Ishfaq[1] | Farzana Noor[2] | A. A. Bhat[3]

[1]School of Mathematics and Statistics, Central South University, Changsha, China | [2]Department of Mathematics and Statistics, International Islamic University, Islamabad, Pakistan | [3]Department of Mathematical Sciences, Islamic University of Science and Technology, Pulwama, India

Correspondence: Farzana Noor (farzana.akhtar@iiu.edu.pk)

Received: 12 May 2025 | **Revised:** 30 September 2025 | **Accepted:** 7 January 2026

Keywords: 2-component mixture model | annual maximum series | Bayesian analysis | flood event prediction | Gumbel type-II distribution | peak over threshold | weighted inverse Rayleigh distribution

ABSTRACT

This article develops a two-component mixture model combining the weighted Inverse Rayleigh (WIR) distribution and Gumbel Type-II distribution for the estimation and prediction of flood events. The study utilizes 29 years (1990–2018) of flood data from the Federal Flood Commission (FFC) of Pakistan for the Jhelum River, using two gauging stations (Mangla and Rasul) across two catchments (U/S and D/S). Two distinct approaches, Annual Maximum series (AMS) and Peak over threshold (POT), are used for the estimation of parameters of the mixture models in a Bayesian context. Bayesian analysis is performed using the Square Error Loss Function (SELF) and Quadratic Loss Function (QLF) with gamma and beta priors. Bayes estimators and their posterior risks for both the Weighted Inverse Rayleigh and Gumbel Type-II distributions are derived. For the Gumbel type-II distribution, both the shape and scale parameters are treated as random. A comprehensive simulation study is conducted to examine the behavior of derived Bayes estimators and their posterior risks. The study also compares various loss functions and aims to explore a well-fitted distribution. Additionally, it aims to determine return periods for accurate flood event predictions.

1 | Introduction

Global warming, as an international concern, is leading to environmental changes and posing serious risks to the economies of developing countries. Pakistan, with its limited resources and socio-economic vulnerabilities, is considerably more vulnerable to the repercussions of climate change. The accelerating melting of ice sheets in South Asia increases the potential risk of floods in Pakistan and neighboring countries in the coming years. Natural disasters and environmental degradation have already caused enormous economic losses in Pakistan, as one of the top 10 countries most affected by frequent and severe natural catastrophes, including floods, droughts, hurricanes, heavy rainfall, and extreme temperatures. Pakistan faces enormous challenges. These disasters continue to have an enormous effect on the population, infrastructure, agriculture, and overall socio-economic stability.

Hosking and Wallis (1997) thoroughly explored flood frequency analysis (FFA) as a statistical method for estimating the frequency of floods and forecasting future events at different return levels. Frequency analysis is used to estimate how frequently a specific event is likely to occur. Chow and Maidment (1988) suggested that the main objective of flood

Abbreviations: AMS, annual maximum series; D/S, downstream; FFA, flood frequency analysis; FFC, Federal Flood Commission of Pakistan; POT, peak over threshold; QLF, quadratic loss function; RMSE, root mean square error; SELF, squared error loss function; U/S, upstream; WIR, weighted inverse Rayleigh; WIR, weighted inverse Rayleigh.