26th International Congress on Modelling and Simulation, Adelaide, SA, Australia, 30 Nov–4 Dec 2025
mssanz.org.au/modsim2025

Development and evaluation of "climate-robust" rainfall runoff model parameter libraries

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Abstract: Prediction of catchment runoff responses under unforeseen climate conditions has long challenged hydrologists. Conceptual rainfall runoff models are employed worldwide to predict runoff for regional water resource management and planning. Obtaining appropriate parameters for these models for future climate conditions requires approaches that extend beyond mere optimisation over historical periods. The body of literature surrounding catchment modelling strongly indicates that rainfall runoff models will often produce poor predictions outside the historic conditions of the calibration period (e.g., Refsgaard et al., 1996; Saft et al., 2016; Vaze et al., 2010).

Because climate variability over the available observational data may be very limited, calibrations may benefit from the idea that, for any future climate, the possibility exists that for a given location, a similar climate exists in the present at another location. Given the accessibility of historic climate and streamflow data across Australia, it is simple to compute observed rainfall runoff coefficients for many catchments across the continent. Simultaneously, using a single parameter set of a conceptual rainfall runoff model, the simulated rainfall runoff coefficient can be produced for each of these headwater catchments. This allows the evaluation of the ability of a parameter set to reproduce correct rainfall runoff coefficients over a range of conditions for a range catchments. Furthermore, the difference between the simulated and observed rainfall runoff coefficients over all the catchments can be characterised statistically, which allows uncertainty estimation of the rainfall runoff parameters under a Bayesian framework. The result could be used to generate a parameter library that would exclude parameter sets that perform poorly over a range of conditions.

This study uses data from 207 catchments across Australia to obtain rainfall runoff model parameters that most closely produce expected rainfall runoff coefficients (ratio of runoff to rainfall) for a wide range of different catchments' environmental conditions. Two widely used models, GR4J and Sacramento, were evaluated. In a two-step process, parameters were first selected that could adequately reproduce observed runoff coefficients across the 207 catchments. Acceptable parameter sets were stored in a library from which, in the second step, parameters were selected for each individual catchment according to various goodness-of-fit metrics. Performance of this calibration approach was compared with a classical optimisation employed for each catchment (DELO - Differential Evolution Local Optimisation).

Results showed that there are performance trade-offs when using the parameter library based calibration compared to DELO for metrics such as Nash-Sutcliffe efficiency and percentage bias. Simulations using the parameter library based calibration behaved more realistically under perturbed climate conditions, compared to DELO parameters. Results also showed that estimates of rainfall runoff coefficient using DELO parameters may be tolerable at many sites when rainfall is reduced by no more than 25%. However, there is a high risk of under- or over-estimating rainfall runoff coefficients at larger reductions. The GR4J and Sacramento parameter libraries generated by the study can be found at https://doi.org/10.25919/w0vx-3g85.

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Keywords: *Non-stationarity, Rainfall runoff, Aridity, Climate change*