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

Muti-variable calibration to improve robustness of landscape models under change

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Abstract: Hydrological models are essential tools for estimating water balance components, evaluating management scenarios, and assessing extreme events. However, their performance often degrades under conditions different to those used for calibration, such as changes in land uses or future climate scenarios. This study aims to enhance the robustness of landscape models through multi-variable calibration and dynamically representing land use change.

The Australian Water Resources Assessment Landscape (AWRA-L) model was applied to catchments in the southeast of South Australia. The model includes five hydrological response units (HRUs) representing deep rooted vegetation, shallow rooted vegetation, irrigation, permanent water and urban areas. An approach to allow the proportion of each HRU within a cell to change over time while maintaining the water balance was developed, enabling simulation of land use change.

Traditionally, hydrological models are calibrated to observed streamflow data. However, streamflow alone often lacks sufficient information to uniquely identify parameter values, representing an ill-posed and identifiability issue, particularly when conditions change over time. Hence, along with streamflow, groundwater levels, soil moisture, and leaf area index (LAI) datasets were also included in the model calibration. Limited trade-off between the accuracy of the modelled streamflow and other datasets was found in a multi-variable calibration approach, particularly for the higher runoff catchments considered.

To evaluate model robustness, the Robustness Assessment Test (Nicolle et al., 2021) was expanded into a Bayesian framework, termed the Bayesian Regression Robustness Assessment Test (BRRAT). This approach extended the original pass/fail approach, based on a 5% significance level, to quantify improvements in model robustness, defined as a reduced relationship between relative error in modelled annual streamflow and the input climatic variables, in this case rainfall. By applying the BRRAT to the AWRA-L results, increased model robustness was found through multi-variable calibration, expected to be due to improved representation of the internal catchment processes by including the additional dataset in the calibration.

Scenarios of land use and climate change demonstrated differences in the modelled output under extrapolated conditions compared to the calibration period. Results suggest the streamflow only calibration was inconsistent with the expected changes in the water balance, which was not the case for the multi-variable calibration. Changes in water balance components of recharge and runoff were greater for the model calibrated to multiple datasets, due to increased modelled evapotranspiration.

This study demonstrates the value of multi-variable calibration for enhancing model robustness. The BRRAT offers a systematic, efficient method to assess robustness improvements from a single model simulation, avoiding the need for multiple, time consuming, split-sample recalibrations. These advancements support more confident use of hydrological models in water resource decision-making, particularly in regions undergoing significant environmental change.

REFERENCES

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Keywords: *climate change, land use change, hydrological modelling, model robustness*