Assessing the applicability of the MARRMoT Toolbox for continuous rainfall-runoff modeling of small Hungarian catchments

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INTRODUCTION

In engineering practice, one of the most important tools is modeling. In recent decades, there have been several programs developed to help in the building of specific and complex models, including in the field of hydrology. There are many reasons why we need hydrological, or more specifically, rainfall-runoff models. According to Beven (*2012*), the main reason is a result of the limitations of hydrological measurement techniques, as we are not able to measure everything. On the other hand, rainfall-runoff modeling can help us in formalizing knowledge about hydrological systems, which is an important way of developing an area of science. However, the ultimate aim of using rainfall-runoff models is prediction. The models can help the decision-making process about a hydrological problem, whether that be in water resources planning, flood protection, mitigation of contamination, or other areas.

In Hungary, there are no practical guidelines about the most applicable modeling software, model types, calculation methods, parameter values, data processing methods or even data sources in the case of rainfall-runoff modeling. This research explores the applicability of the Modular Assessment of Rainfall-Runoff Models Toolbox (MARRMoT) developed by Knoben et al. (*2019*) for two small Hungarian catchments, namely Torna-creek and Arany-creek. With the help of the toolbox, the current research examines and compares three sources of precipitation data: gauging station data, homogenized and interpolated gridded data, and reanalysis data, and analyses the results of 47 different conceptual models. The study reflects on the applicability of the toolbox and its built-in models and optimization method.

STUDY AREA

The current study is based on two different catchments, namely Arany and Torna, examined at the outlet point of Olad and Városlőd. Figure 1. shows an overview of their location in the western part of Hungary. The catchment of Arany-creek has an area of 106.44 km^2, while the catchment of Torna-creek is relatively smaller, with an area of 20.17 km^2.

The climate in the region is moderately cool and moderately humid. If we review the land cover of these watersheds, Arany has a high ratio of forests and artificial landscapes, while Torna is characterized by forests and arable lands. The elevation differs significantly within the catchment of Arany, while Torna is characterized by a milder basin slope.

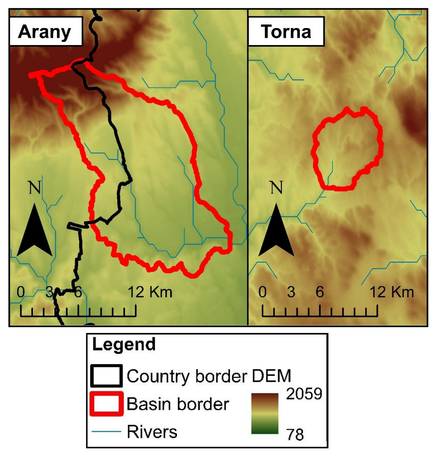

Figure 1 – Overview of the study basins.

MATERIALS AND METHODS

Data and data processing

- Discharge: staff gauges
- Temperature: from station data (*HungaroMet*)
- Potential evaporation: from station data (*HungaroMet*)
- Precipitation:
  - reanalysis (ECMWF, *Sabater, 2019*),
  - gauging station data (HungaroMet),
  - homogenized, interpolated gridded data series (*HungaroMet*)

The quality of the data was checked to exclude measurement errors, then the different data sources were compared. In this study, the warm-up period was 1 year. The calibration was performed using 2 years of the available time series, while we used 1 year for the validation of the models.

Rainfall-runoff models – MARRMoT (*Knoben et al., 2019*):

- MARRMoT is a freely available MATLAB-based toolbox.
- The toolbox has 47 different models.
- All models are conceptual, deterministic, and lumped.
- The models have 1-24 parameters.
- Only 3 inputs are needed: temperature, potential evaporation, and precipitation.
- The optimization method of the toolbox is the Covariance Matrix Adaptation Evolution Strategy (CMA-ES*) (Trotter et al., 2022).*

RESULTS AND CONCLUSIONS

Based on the results, we derived three key conclusions. First, **data from gauging stations leads to the best model performance** using the MARRMoT toolbox. The analyses of the three precipitation data types showed that **significant differences can be between these precipitation data sources which highlights the importance of input data selection**. Second, **the CMA-ES optimization method** built into the toolbox in recent developments (*Trotter et al., 2022*) **should be used with caution**, as it does not always lead to a global optimum. Additionally, the research results show that **out of the 47 different models tested, only a few were capable of producing acceptable simulation results**.

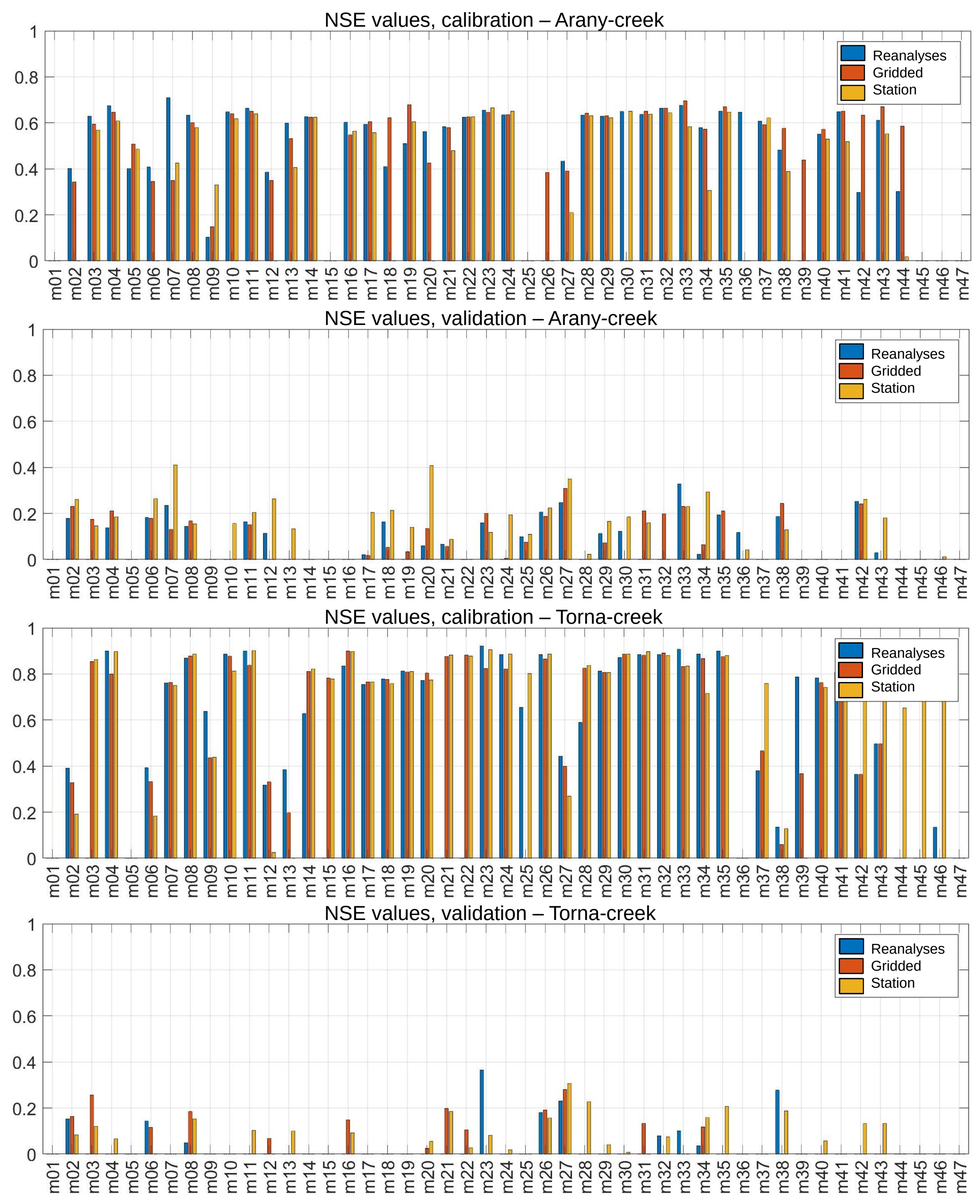

Figure 2 – Nash-Sutcliffe efficiency (NSE) values of the model simulations.

DISCUSSION

The results show that MARRMoT can yield satisfactory results, but **most of the models showed low efficiency during validation**. The reasoning can be that the models were developed for catchments with significantly different characteristics compared to the Hungarian catchments involved in this current research, or they may not represent hydrological processes that are notable in the case of these small Hungarian catchments. **These findings emphasize the need for implementing a new model structure** that can simulate the hydrological processes of these Hungarian catchments more sufficiently. Furthermore, as the quality of the input data can remarkably influence the models' effectiveness, **all input data has to be reviewed carefully** which can cause difficulties if the data source has hidden errors. In the continuation of the research, we will involve more watersheds in the analysis, examine data correction options, implement new model structures, and analyze the possibility of incorporating other optimization methods.

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