Modeling Runoff Where Data Are Scarce: A Multi-Approach Synthesis in Snow-Influenced Semi-Arid Basins — Case Study of the Oum Er Rbia Basin, Morocco

Houda Laghmame[1]*, Karima Nifa[2], Siham Acherki[3], Haytam Elyoussfi[4], Mohammed Garnaoui[2], Mostafa Bousbaa[4], Bouchra Bargam[3], Abdelghani Boudhar[1, 3]

[1] *Cadi Ayyad University/ Faculty of Sciences and Techniques, Marrakech, Morocco*
[2]*Mohammed VI Polytechnic University, Centre Urban Systems, Benguerir, Morocco*
[3]*Mohammed VI Polytechnic University/International Water Research Institute, Ben Guerir, Morocco*
[4]*Mohammed VI Polytechnic University/ Center for Remote Sensing Applications, Benguerir, Morocco*

**h.laghmame.ced@uca.ac.ma*

ABSTRACT

Runoff modeling in the semi-arid, snow-influenced Oum Er Rbia basin (OER), Morocco, is constrained by scarce ground observations and the lack of monitoring in high-elevation zones, making reliable prediction in poorly-gauged sub-catchments a persistent challenge. The OER sustains major irrigation schemes, hydropower, and downstream water supply, where mountain snowmelt is a key contributor to river flow. This contribution synthesizes recent multi-approach advances achieved on the OER, organized along three complementary lines, and outlines the direction they collectively point toward.

First, on the multi-source and multi-scale representation of snow, multi-source satellite snow products were merged and statistically downscaled to produce high-resolution snow forcing, and snowmelt water outflow was estimated by combining in-situ measurements, downscaled ERA5 reanalysis and remote-sensing data within a SNOW-17 framework. This line shows that consistent, spatially distributed snow inputs can be reconstructed in this poorly monitored mountain basin, enabling a shift from point-scale to basin-scale simulation.

Second, on conceptual modeling and transferability, a large ensemble of more than forty conceptual hydrological structures was benchmarked for performance, stability, and parameter sensitivity, complemented by HBV regionalization across gauged and ungauged sub-catchments. This line indicates that only a limited subset of structures is robust, and that transfer to ungauged catchments remains constrained by parameter instability and sensitivity.

Third, on data-driven approaches, AI-based methods and deep-learning configurations (notably LSTM) were tested for daily streamflow simulation and for their transferability. This line confirms strong predictive skill in gauged conditions, but a marked dependence on data availability and a degradation of performance under transfer to ungauged areas.

Taken together, these results expose a complementary tension: physically interpretable conceptual models are robust yet poorly transferable, while data-driven models are powerful yet data-hungry. By integrating snow, conceptual and data-driven advances within a single perspective, this synthesis clarifies where each approach succeeds or fails, and motivates their combination for more reliable runoff prediction in ungauged settings. This convergence highlights hybrid conceptual–data-driven modeling, combining physical consistency with predictive skill, as a promising way forward for ungauged, data-scarce semi-arid basins.

Keywords: Multi-approach modeling; multi-scale; multi-source data; Poorly-gauged semi-arid basins; Oum Er Rbia basin.