

# On the Calibration of Spatially Distributed Hydrologic Models for Poorly Gauged Basins: Exploiting Information from Streamflow Signatures and Remote Sensing-Based Evapotranspiration Data

Tadesse Alemayehu <sup>1,2,\*</sup>, Hoshin V. Gupta <sup>3</sup>, Ann van Griensven <sup>1,4</sup> and Willy Bauwens <sup>1</sup>

<sup>1</sup> Hydrology and Hydraulic Engineering, Vrije Universiteit Brussel (VUB), 1050 Brussels, Belgium; ann.van.griensven@vub.be (A.v.G.); wbauwens@vub.ac.be (W.B.)

<sup>2</sup> Blackland Research and Extension Center, Texas A&M AgriLife Research, Temple, TX 76504, USA

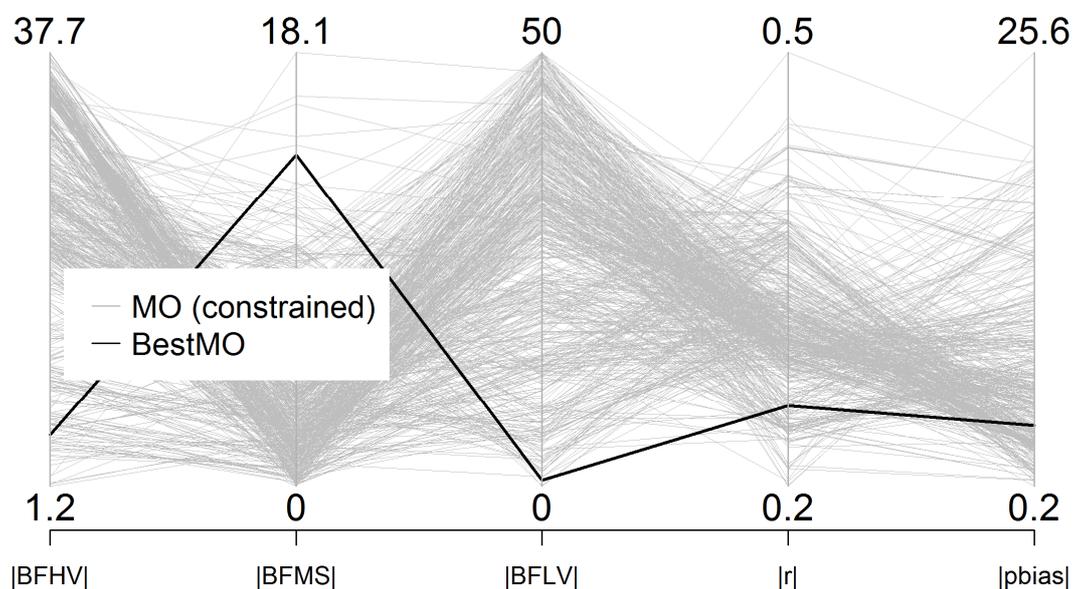
<sup>3</sup> Department of Hydrology and Atmospheric Sciences, The University of Arizona, Tucson, AZ 85721, USA; hoshin@email.arizona.edu

<sup>4</sup> Department of Water Science and Engineering, IHE Delft Institute for Water Education, 2611 Delft, The Netherlands

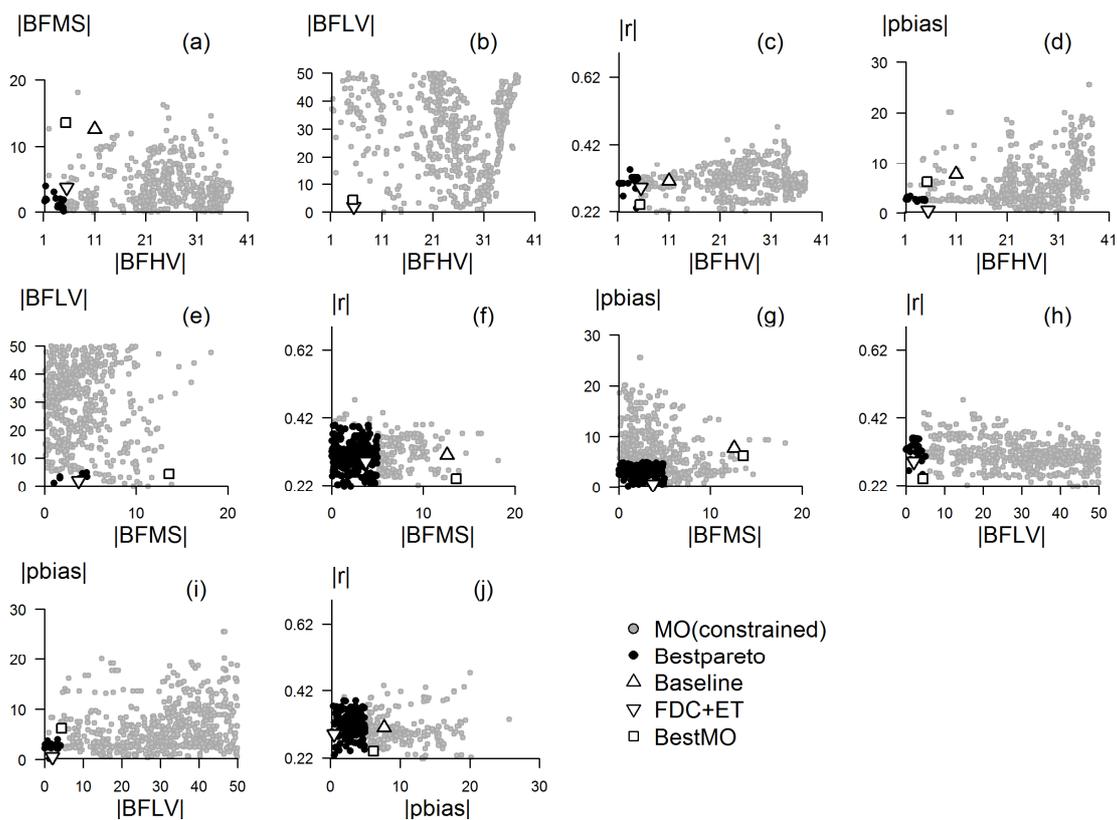
\* Correspondence: tadesse.abitew@brc.tamus.edu

## Introduction

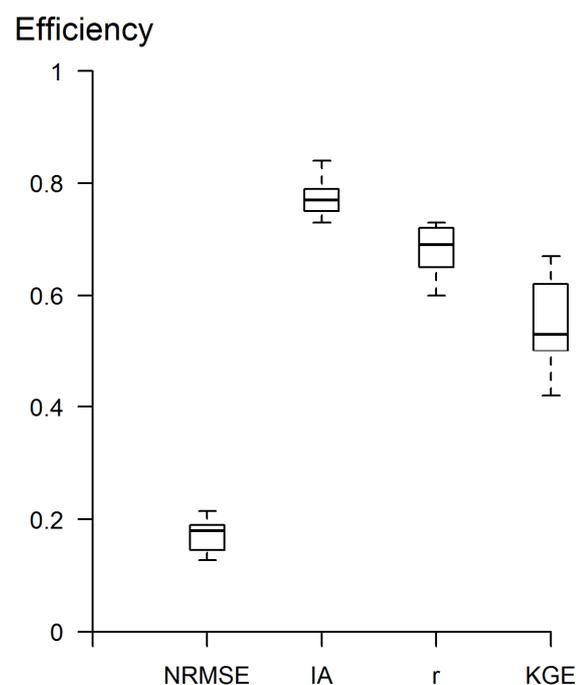
The purpose of these additional plots is to provide more information about the modeling results at a different location in addition to the ones presented in the main manuscript.



**Figure S1.** The trade-off in evaluation criterion in a constrained search using Borg MOEA for the head water region (MM) based on streamflow signatures and RS-ET. The location where the line intersects each vertical axis designates the relative objective value. The grey lines represent the efficiency measures in the provided parameter space (MO (constrained)) while the solid blackline represents the selected best trade-off (BestMO) from the Pareto solution set. Note that the correlation coefficient is represented as 1-r.



**Figure S2.** Trade-off in two evaluation criterion spaces for the head water region (MM). The gray dots show all the evaluations in the constrained search (MO constrained); the black dots (Bestpareto) represent the best trade-off for the respective bi-criterion with a bias lower than 5% and a correlation higher than 0.65. The upward triangle and downward triangle markers denote evaluations for the baseline and manually calibrated model (FDC+ET), respectively. The square marker represents the selected best trade-off taking into account all the objectives (BestMO).



**Figure S3.** Performance summary of the SWAT model for simulating the daily streamflow (2002–2007) using 13 Pareto set parameters. Legend: NRMSE = Normalized Root Mean Square Error; d= Index of Agreement, r= Pearson correlation coefficient and KGE= Kling-Gupta efficiency.

(a) Streamflow signatures			(b)		
	FDC+ET	BestMO		FDC+ET	BestMO
BFHV	+	+	BFHV	-	-
BFMS	+	+	BFMS	+	-
BFLV	+	+	BFLV	+	+

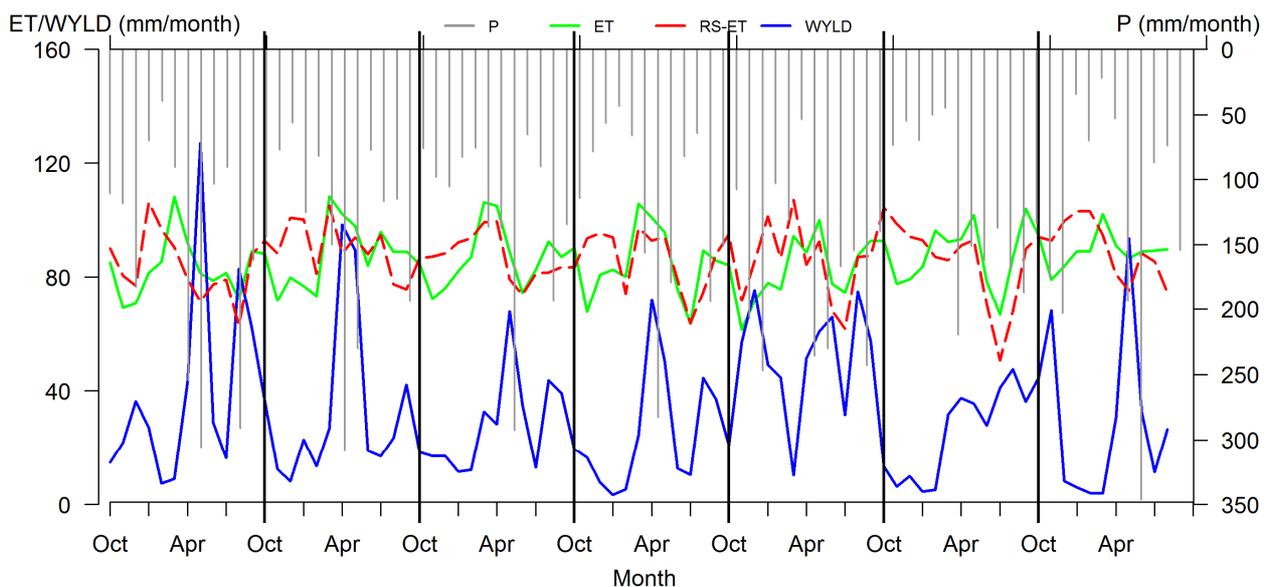
(c) Evapotranspiration			(d)		
	FDC+ET	BestMO		FDC+ET	BestMO
FRSE	+	+	FRSE	-	+
RNGE	+	+	RNGE	+	-
RNGB	+	+	RNGB	-	-

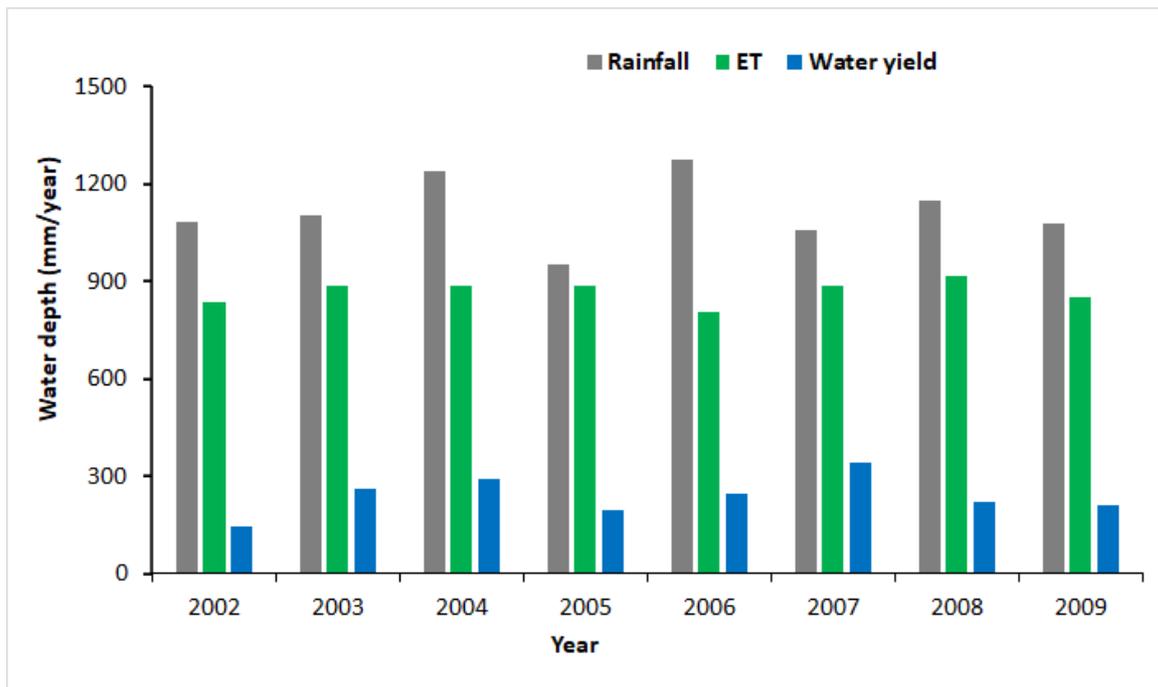
**Legend**

- 
 + **RP ≥ 50%**- 
 + **25% ≤ RP < 50%**- 
 + **0 < RP < 25%**- 
 - **-5% RP ≤ 0**- 
 - **RP < -5%**

**Figure S4.** Comparison of relative performances using SWAT model calibrated based on streamflow signature measures only (FDC) as reference for streamflow signature bias measures at the Nyangores (a) and the Mara (b) Rivers, and for evapotranspiration using correlation (c) and percent of bias (d). FDC+ET: calibration using streamflow signature measures and remote sensing evapotranspiration and BestMO: automatic multi-objective calibration based on selected best parameter set from the Pareto set solutions.



**Figure S5.** The monthly water balance dynamics for 2002–2009 over the Nyangores watershed (HW) as simulated by SWAT. Note that the months are arranged according to the hydrological year (Oct–Sept).



**Figure S6.** Simulated annual water balance for 2002–2009 over the Mara River Basin.