

## Supplementary material

### Hydrology MDPI

# Prediction at Ungauged Catchments through Parameter Optimization and Uncertainty Estimation to Quantify the Regional Water Balance of the Ethiopian Rift Valley Lake Basin

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**Table S1.** Correlation coefficients (CC) between catchment properties and model parameters.

CC	$\beta$	$F_c$	$K_0$	$K_1$	$K_2$	$L_P$	$M_{MAXBAS}$	$P_{MAX}$	$V_{UZL}$
(a) Correlation coefficient on the normal scale									
Drainage area	0.24	0.18	0.22	-0.44	0.2	0.31	0.11	-0.15	-0.07
Drainage density	-0.04	-0.3	-0.05	0.57	-0.05	-0.21	-0.25	-0.2	-0.46
Slope	-0.7	0.52	0.01	-0.03	-0.45	-0.03	0.65	0.41	0.41
Elevation	0.6	-0.46	-0.03	0.42	0.05	0.27	-0.21	-0.54	-0.14
Catchment index	-0.32	0.14	-0.12	0.17	-0.43	0.04	0.52	0.19	0.12
Permeability	-0.09	0.08	0.35	-0.45	-0.01	0.3	0.23	-0.09	0.06
Porosity	0	-0.01	-0.34	0.31	-0.13	-0.32	-0.08	0.19	0.02
P/PE (Wi)	-0.61	0.43	0.35	-0.28	-0.47	-0.05	0.52	0.32	0.41
Annual RF	-0.67	0.38	0.27	-0.3	-0.5	-0.2	0.48	0.44	0.44
(b) Rank correlation coefficient									
Drainage area	0.17	0.06	0.23	-0.63	0.38	0.25	0.02	0.00	0.04
Drainage density	-0.13	-0.28	-0.08	0.62	-0.29	-0.34	-0.19	-0.05	-0.27
Slope	-0.68	0.57	-0.18	-0.02	-0.28	-0.13	0.55	0.36	0.50
Elevation	0.49	-0.40	0.01	0.51	-0.16	0.34	-0.16	-0.49	-0.26
Catchment index	-0.16	-0.11	-0.09	0.37	-0.43	0.04	0.27	-0.09	-0.11

Permeability	0.26	0.12	0.14	-0.33	0.25	0.51	0.26	-0.08	0.15
Porosity	-0.30	-0.06	-0.19	0.22	-0.31	-0.55	-0.05	0.26	0.04
P/PE (Wi)	-0.70	0.35	0.29	-0.23	-0.22	-0.16	0.42	0.41	0.42
Annual RF	-0.68	0.34	0.20	-0.28	-0.32	-0.23	0.42	0.47	0.54
(c) Log transformed correlation coefficient									
Drainage area	0.20	0.03	0.34	-0.57	0.23	0.34	0.09	0.02	0.06
Drainage density	-0.08	-0.25	-0.17	0.56	-0.19	-0.26	-0.23	-0.23	-0.36
Slope	-0.68	0.53	-0.19	-0.13	-0.32	-0.10	0.54	0.40	0.58
Elevation	0.61	-0.30	-0.09	0.58	-0.17	0.31	-0.14	-0.53	-0.37
Catchment index	-0.21	0.08	-0.30	0.29	-0.44	0.07	0.36	-0.04	-0.07
Permeability	0.19	-0.08	-0.27	0.63	-0.02	-0.31	-0.23	-0.04	-0.11
Porosity	0.18	-0.09	-0.29	0.54	-0.11	-0.27	-0.13	0.01	-0.05
P/PE (Wi)	-0.61	0.39	0.21	-0.43	-0.28	-0.14	0.51	0.34	0.41
Annual RF	-0.67	0.31	0.12	-0.39	-0.29	-0.28	0.45	0.40	0.46

*For permeability the Log transformation results in the complex numbers, thus the absolute values of the variables were taken for the correlation analysis.*

**Table S2.** Catchment properties that are derived for streamflow prediction in the ungauged catchments using the 14 parameter sets obtained by the weighted regression.

Ungauged cats no	Area [km <sup>2</sup> ]	DD [km/km <sup>2</sup> ]	Mean slope [%]	Mean Elev[m]	Cat Index [m/km]	Permeability [log10 m <sup>2</sup> ]	Porosity [-]	Wi [-]	P [mm]
1	5324.01	0.075	16.22	2037.1	10.07	-12.194	0.07	0.85	923.6
2	591.54	0.21	13.99	719.63	10.12	-10.73	0.06	0.86	842.6
3	181.16	0.5	13.49	1772.8	17.27	-12.07	0.022	1.06	1140.1
4	130.86	0.3	21.13	1795.4	10.92	-12.34	0.087	1.04	1140.1
5	151.33	0.56	21.55	1557.7	43.55	-11.51	0.048	0.85	928.9
6	185.1	0.44	29.6	2237.9	57.08	-11.58	0.106	1.03	1265.5
7	1791.1	0.12	25.73	1236.8	10.41	-11.59	0.034	0.58	655.6
8	233.45	0.32	33.53	1825.1	59.34	-11.93	0.072	0.94	1076.2
9	203.97	0.45	25.55	1102.4	28.68	-11.05	0.043	0.61	631.7
10	521.98	0.31	11.19	679.33	9.44	-10.94	0.023	0.63	660.6
11	143.19	0.49	11.24	1697.1	6.19	-11.76	0.005	0.69	798
12	62.66	0.96	13.24	1787.2	27.16	-12.34	0.036	0.68	848.4
13	78.96	0.81	16.72	2252.3	41.57	-12.5	0.09	0.7	848.4
14	140.85	0.48	16.67	2158.7	17.93	-11.93	0.08	0.87	995.7
15	603.71	0.43	14.32	2159.3	19.29	-12.5	0.09	0.92	995.7
16	929.61	0.27	12.8	1802.7	8.74	-12.37	0.092	0.94	1028.8
17	217.98	0.55	17.15	2536.3	37.29	-12.12	0.085	0.95	995.7
18	189.71	0.5	19.23	2540.1	34.28	-12.12	0.082	0.71	848.4
19	189.09	0.43	18.8	2406.1	38.12	-12.12	0.079	0.71	848.4
20	241.08	0.34	25.61	1586	29.87	-11.73	0.065	0.98	1076.2
21	240.43	0.36	17.58	1310.2	16.17	-11.97	0.056	0.88	928.9
22	214.66	0.41	26.15	1686.7	32.88	-11.58	0.107	1.05	1265.5
23	762.79	0.19	12.7	875.24	16.74	-11.44	0.003	0.88	842.6
24	676.87	0.25	10.64	975.03	17.64	-11.73	0.033	0.84	842.6
25	1307.8	0.17	7.93	1159.5	9.23	-11.38	0.069	0.5	545.6
26	434.37	0.25	29.84	1476.9	36.78	-11.88	0.064	0.6	631.7
27	749.14	0.21	18.97	1294.4	15.55	-11.56	0.099	0.6	631.7
28	892.62	0.21	15.98	995.88	7.23	-11.75	0.05	0.48	502.2
29	1164.9	0.18	21.67	1536.2	15.96	-11.05	0.094	0.47	502.2
30	153.06	0.76	15.67	2534	42.81	-12.5	0.089	0.74	848.4
31	231.39	0.54	9.08	1643.2	7.37	-12.24	0.088	0.66	798
32	290.84	0.41	9.5	1801.1	9.48	-11.21	0.079	0.77	890.3
33	3424.4	0.17	20.18	1592.3	10.13	-11.75	0.048	0.8	896.1
34	2062.2	0.116	13.88	1933.8	4.41	-12.035	0.068	0.68	737.6
35	631.3	0.308	12.12	2085.6	16.37	-11.885	0.05	1.09	1128.3

*DD-Drainage density, Wi – Wetness index, P - Annual average precipitation*

**Table S3.** The maximum NSE on the monthly scale for the best parameters derived from calibration, validation, and stable sets, and standard deviations (std) of monthly NSE for calibration and validation.

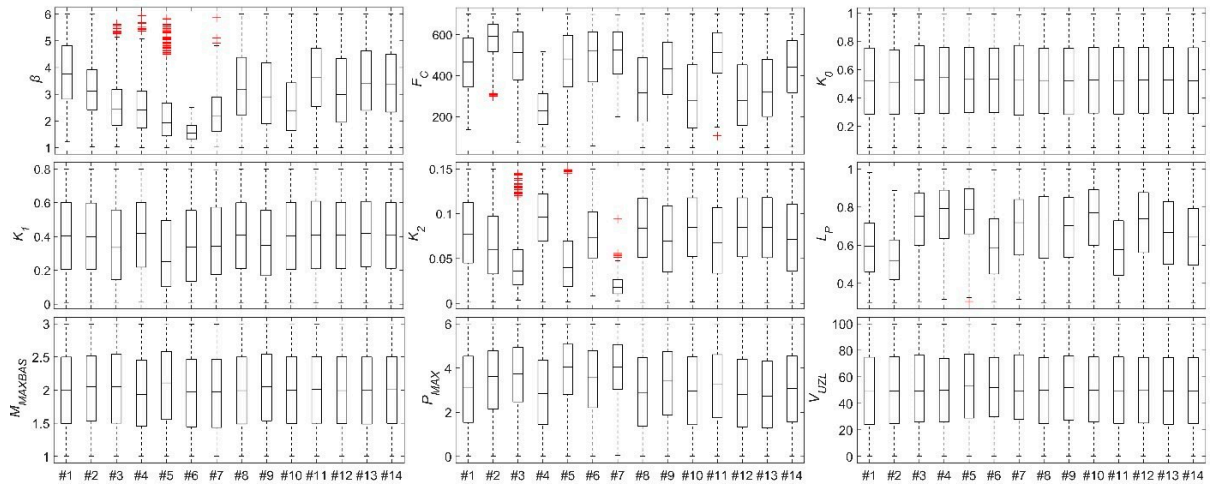
Catchment No	gauge location	Monthly NSE (Calibration)	Monthly NSE (Validation)	NSE monthly (stable parameters)	std of monthly NSE (Calibration)	std of monthly NSE (Validation)
#01	Bilate@Tena	0.82	0.78	0.75	0.086	0.248
#02	Gelana@Tore bridge	0.75	0.84	0.67	0.057	0.098
#03	Gidabo@Measso	0.77	0.74	0.69	0.067	0.252
#04	Gedemso near Langan	0.53	0.70	0.51	0.007	0.048
#05	Woito @ bridge	0.63	0.69	0.58	0.025	0.055
#06	Hamassa@Wajifo	0.60	0.72	0.55	0.022	0.056
#07	Hare	0.72	0.48	0.70	0.057	0.412
#08	Katar@Abura	0.83	0.87	0.80	0.088	0.244
#09	kulfo@Arbaminch	0.80	0.52	0.80	0.065	0.339
#10	Meki@Meki village	0.86	0.96	0.79	0.097	0.133
#11	Gidabo@Bedesa	0.71	0.84	0.71	0.050	0.052
#12	Katar@Fete	0.75	0.88	0.69	0.064	0.386
#13	Katar@Timela	0.83	0.86	0.80	0.079	0.084
#14	Gidabo@Aposto	0.79	0.89	0.79	0.073	0.264

**Table S4.** Evaluation of the three different regression models from calibration, validation, and stable sets on both calibration (1995-2002) and validation periods (2003-2007). NSE was calculated on the Log transformed scale of observed and simulated discharge.

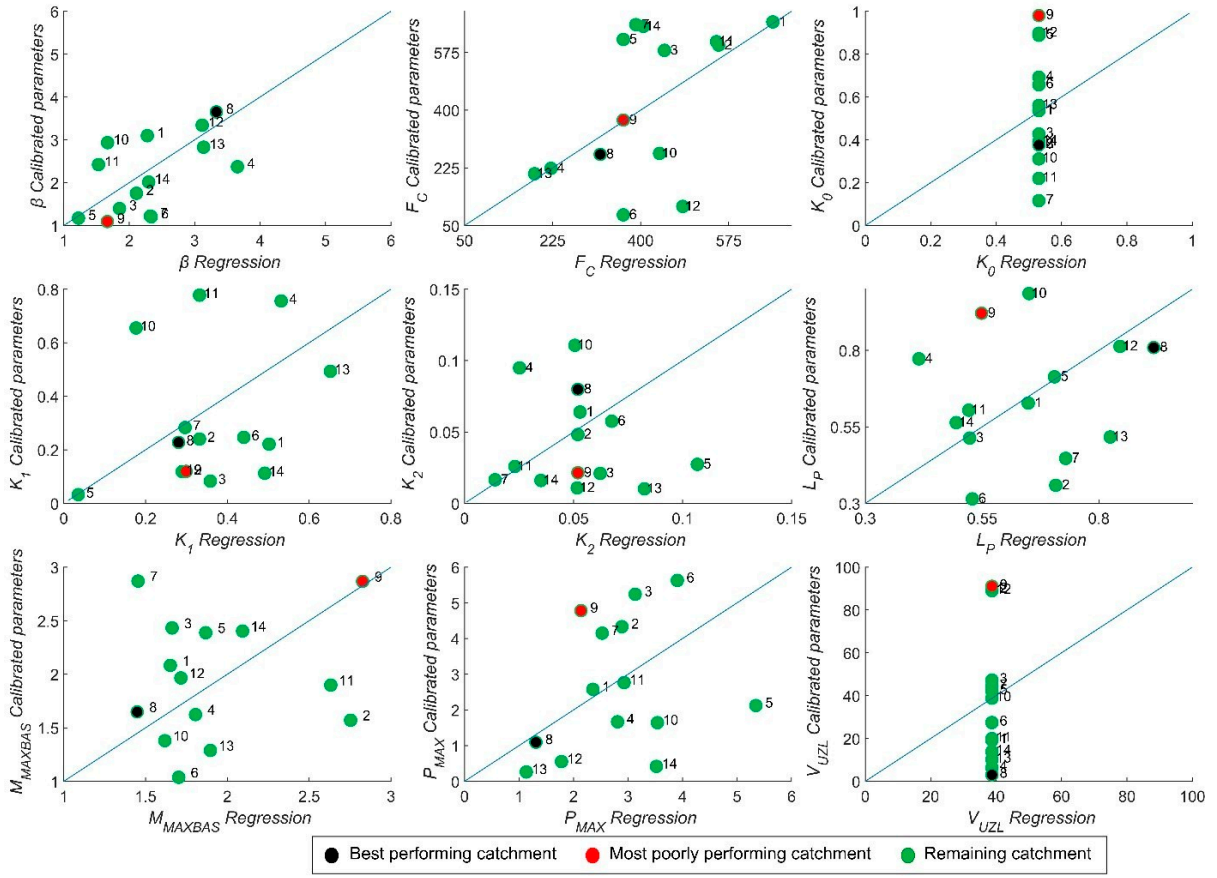
Catchment No	Log NSE on calibration			Log NSE on validation		
	NSE REGcal	NSE REGval	NSE REGstable	NSE REGcal	NSE REGval	NSE REGstable
#01	0.65	0.64	-0.03	0.38	0.46	-0.25
#02	0.54	0.60	0.50	0.47	0.58	0.38
#03	-0.07	0.32	0.56	0.12	0.31	0.50
#04	0.11	-0.91	0.52	0.15	-0.08	0.66
#05	0.50	0.51	0.52	0.05	-0.11	0.34
#06	0.32	0.64	0.60	-0.72	0.57	0.55
#07	0.66	0.62	0.54	-1.04	-0.47	0.02
#08	0.57	-0.43	-0.61	0.73	0.63	0.49
#09	-1.45	-0.33	0.53	-5.91	-2.34	-0.84
#10	0.67	0.59	0.71	0.78	0.64	0.78
#11	0.74	0.81	0.61	0.69	0.82	0.55
#12	0.33	-0.13	-0.50	0.61	0.73	0.71
#13	-2.12	-0.29	-0.99	-1.04	0.24	-0.29
#14	0.13	-0.47	0.16	0.45	0.23	0.62
Median	0.42	0.42	0.52	0.27	0.39	0.50

**Table S5.**  $R^2$  of weighted regression performance for the nine HBV parameters during the leave-one-out cross-validation.

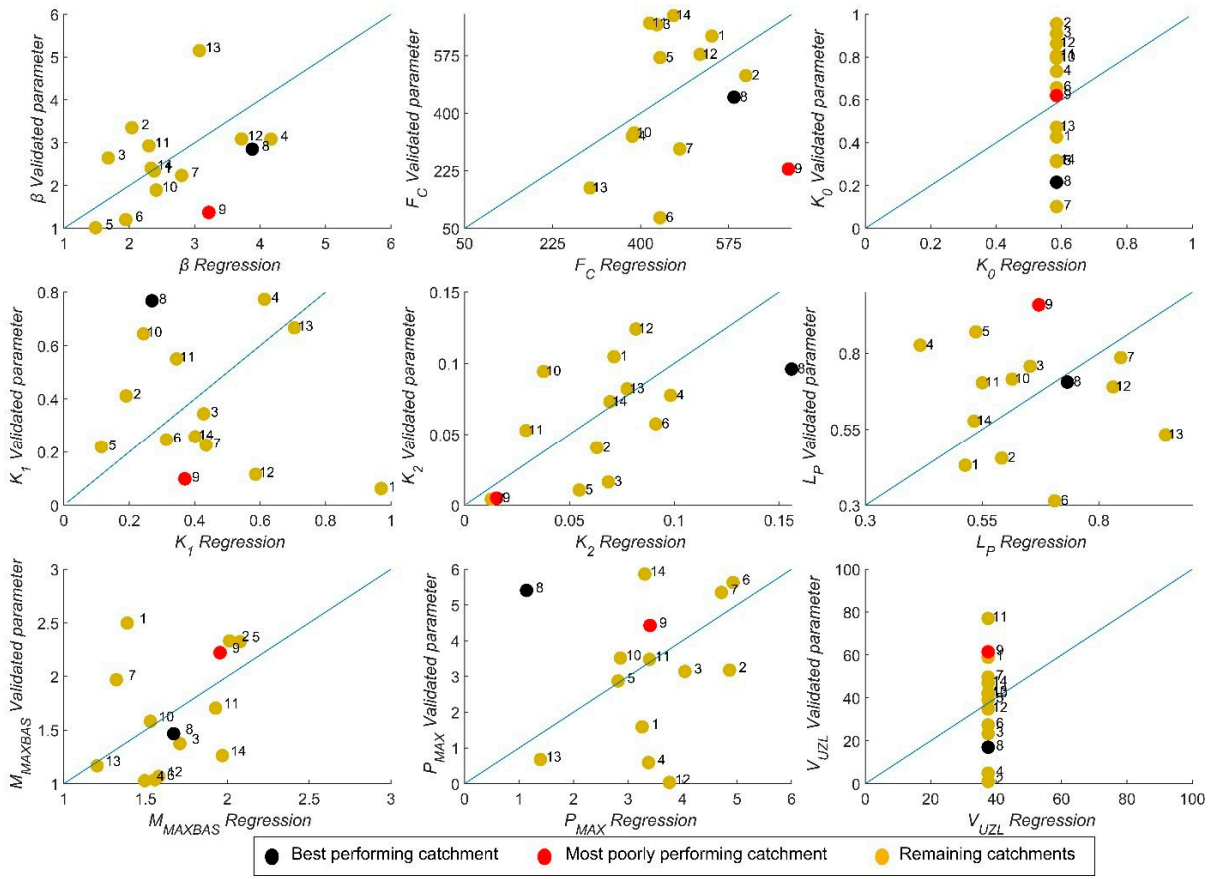
No	Parameters								
	$\beta$ [-]	$F_c$ [mm]	$K_0$ [d <sup>-1</sup> ]	$K_1$ [d <sup>-1</sup> ]	$K_2$ [d <sup>-1</sup> ]	$L_P$ [-]	$M_{MAXBAS}$ [d]	$P_{MAX}$ [mm d <sup>-1</sup> ]	$V_{UZL}$ [mm]
1	0.74	0.52	0.14	0.47	0.49	0.39	0.55	0.56	0.50
2	0.71	0.40	0.13	0.44	0.55	0.41	0.66	0.57	0.43
3	0.70	0.44	0.13	0.59	0.45	0.56	0.61	0.59	0.48
4	0.79	0.57	0.17	0.29	0.50	0.47	0.50	0.63	0.47
5	0.68	0.42	0.00	0.39	0.49	0.51	0.51	0.65	0.49
6	0.73	0.81	0.15	0.46	0.40	0.47	0.47	0.49	0.48
7	0.68	0.62	0.16	0.44	0.56	0.52	0.59	0.60	0.54
8	0.62	0.40	0.16	0.43	0.53	0.34	0.50	0.53	0.55
9	0.69	0.66	0.23	0.44	0.42	0.47	0.58	0.62	0.39
10	0.79	0.42	0.16	0.61	0.55	0.49	0.47	0.60	0.49
11	0.76	0.41	0.12	0.50	0.48	0.37	0.61	0.56	0.55
12	0.66	0.45	0.18	0.43	0.62	0.52	0.52	0.53	0.60
13	0.69	0.38	0.15	0.43	0.60	0.44	0.52	0.50	0.45
14	0.71	0.46	0.13	0.55	0.37	0.56	0.50	0.66	0.55



**Figure S1.** Confined ranges of model parameters derived during model calibration for each catchment.



**Figure S2.** Scatter plots between best parameters estimated from calibration and parameters derived from the regression model. The black circle (catchment #8) represents best performing catchment from parameter estimation and its corresponding parameters from regression. The red circle (catchment #9) represents the most poorly performing catchment by the regression model. For unidentifiable parameters ( $K_0$  and  $V_{UZL}$ ) their median value was taken for the regionalized model.



**Figure S3.** Scatter plots between best parameters estimated from validation and parameters derived from the regression model. The black circle (catchment #8) represents best performing catchment from parameter estimation and its corresponding parameters from regression. The red circle (catchment #9) represents the most poorly performing catchment by the regression model. For unidentifiable parameters ( $K_0$  and  $V_{UZL}$ ) their median value was taken for the regionalized model.