Supplementary Material

S1 Comparison of model performance with studies in the same catchment

Previous studies covering the Broye catchment show varying performance: Zarrineh et al. (2018) calibrated SWAT over 1986–2014, achieving an NSE of 0.60 (calibration) and 0.66 (validation) for daily discharge. Their calibration prioritized low flows, resulting in underestimation of peak flows. Notably, they used precipitation from three local weather stations, which may explain the absence of precipitation bias in their results. Muelchi et al. (2021) applied PREVAH (Viviroli et al., 2009) using projected climate data. For the reference period, model skill was moderate (KGE = 0.69, NSE = 0.51) with a positive precipitation bias of +14.5%. Brunner et al. (2019), also using PREVAH but with (observed) RhiresD precipitation data, reported a KGE of 0.74 and NSE of 0.73 for 1981–2016. However, if we only test the 2010–2016 period (same length as our study period), performance improved (KGE = 0.96, NSE = 0.68). Still, a substantial +22% precipitation bias was noted. Michel et al. (2022) employed Alpine3D (Lehning et al., 2006) with observed station precipitation data, achieving a KGE = 0.77 over 2003–2018. Their flow duration curves indicate a tendency to overestimate high flows and underestimate low flows. These comparisons underline the importance of input data quality. Studies using RhiresD precipitation tend to show positive precipitation biases, while those using station data do not. Although our method of correcting the bias in RhiresD is very simplified, it reduced the positive precipitation bias that was also found in the study of Brunner et al. (2019).

S2 SOC increase results for more states and fluxes

S3 Evaluation of different precipitation products to see if there is a better fit then RhiresD

As reported in Section 3.2, we were not expecting such distinct differences in annual discharge (mm) between the different subcatchments (Appendix A1). The Petit Glâne and the Arbogne must either much less precipitation, or much more water is extracted from the rivers, we assume it is a combination of both factors, since there are no information on the actual water withdrawal amounts available. We assume, that the relatively high annual precipitation in relation to the low discharge could also be the results of an interpolation artifact. We compared the skill of different precipitation products to assess if one would reduce the bias. The compared products are: timeseries of different MeteoSwiss stations (MeteoSwiss, 2025b), the gridded precipitation product RhiresD (MeteoSwiss, 2021), the hourly, stochastic and radar based precipitation product CPC (MeteoSwiss, 2025a) and the probabilistic precipitation ensemble dataset RhydCHprob (MeteoSwiss and Climatology, 2019). Due to the different nature of each product, we try to compare those that cover the same or a similar area.

Table S1. Overview of available data sources by area.

nr	area	Available data by:
1	Payerne (meteostation location)	MeteoSwiss, RhiresD, CPC, RhydCHprob
2	Chables (meteostation location)	MeteoSwiss, RhiresD, CPC, RhydCHprob
3	Avenches (meteostation location)	MeteoSwiss, RhiresD, CPC, RhydCHprob
5	Petit Glane (subcatchment)	RhiresD, CPC, RhydCHprob
6	Arbogne (subcatchment)	RhiresD, CPC, RhydCHprob
7	+/- 0.05° box around Payerne	RhiresD, CPC, RhydCHprob
8	Agrometeo (meteostation)	Agrometeo

Since we could not identify a clear advantage of any of the alternative gridded precipitation products, we decided to keep using the RhiresD dataset with a very simply correction method. Since we saw that nearby meteostations actually showed slightly less precipitation then the RhiresD for subcatchments Petit Glâne and Arbogne, we replaced the gridded timeseries for these subcatchments with the timeseries of the meteostations. To choose the meteostations for each subcatchment, we evaluated the model fit for different combinations. Using the Payerne station data for the Arbogne catchment sand the Chables station

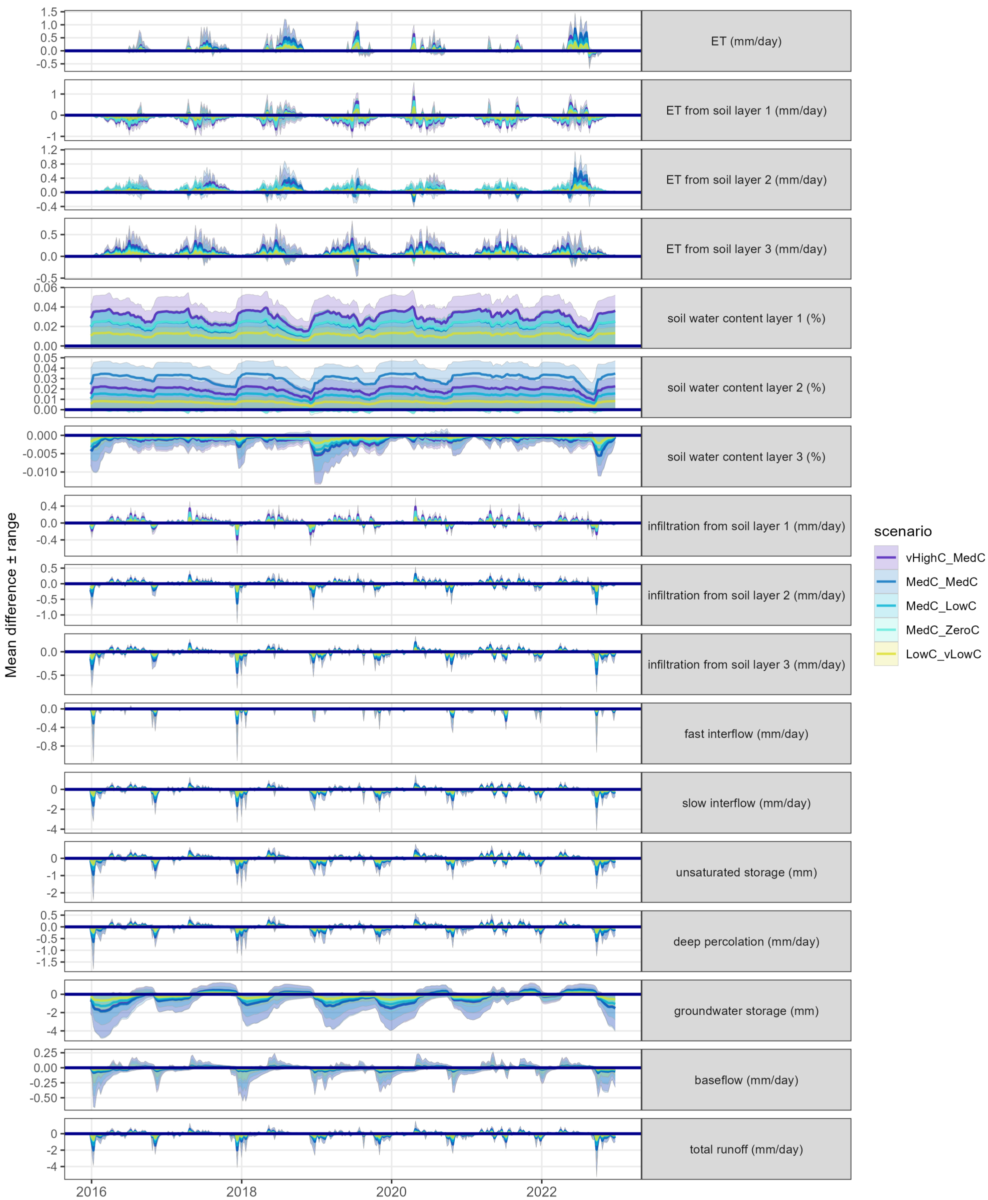


Figure S1. Weekly aggregated differences in states and fluxes for SOC scenarios vs. base scenario

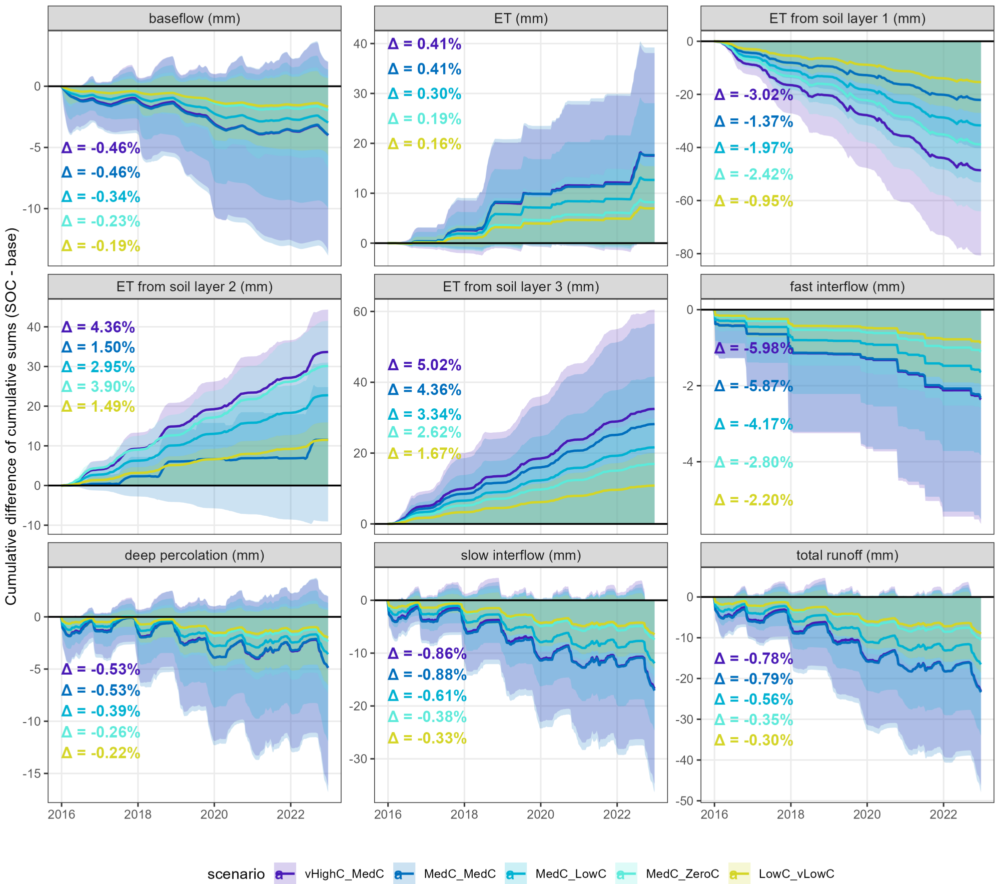


Figure S2. Cumulative difference of cumulative sums for all fluxes for SOC scenarios vs. base scenario

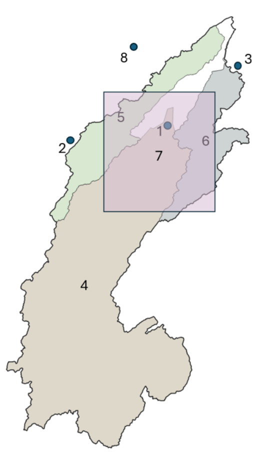


Figure S3. Location of areas reference in Table S1

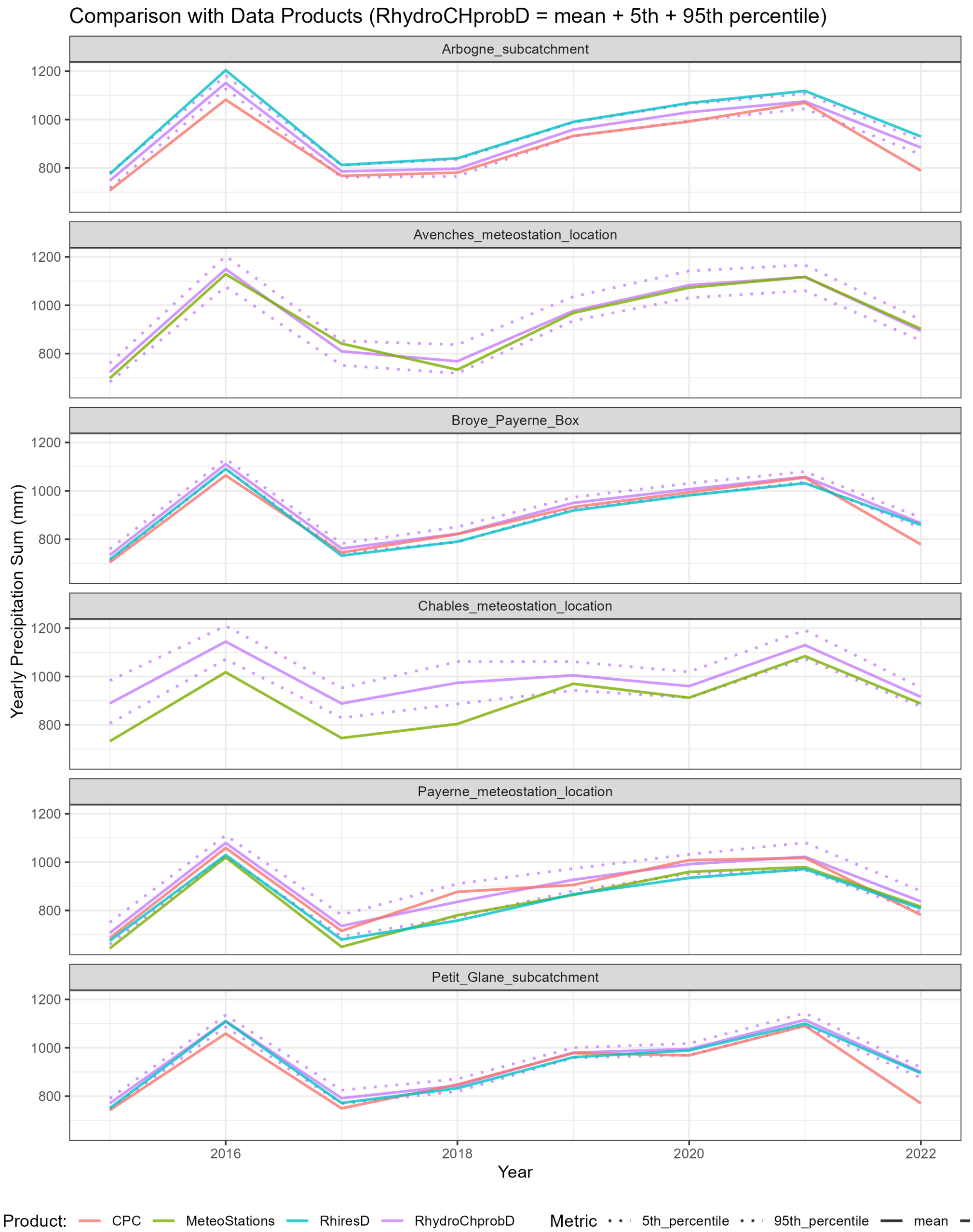


Figure S4. Comparison of annual precipitation sum of different precipitation data products for different locations

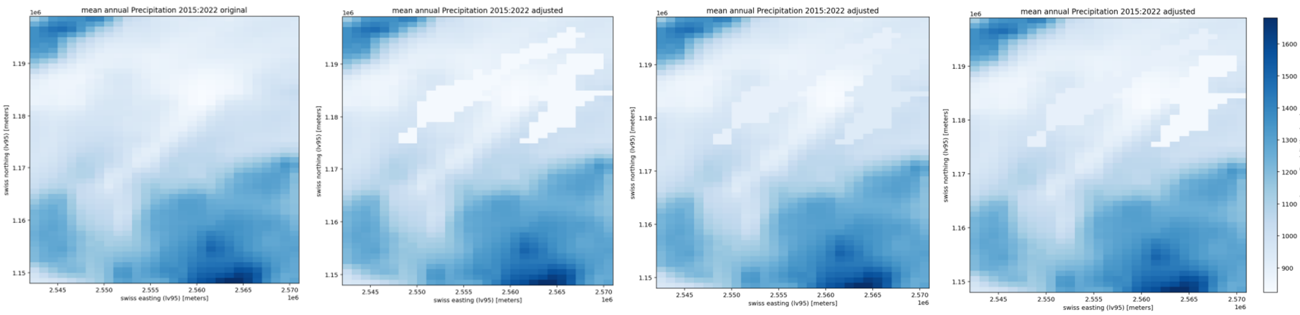
Replacing gridded data with station data for subcatchments Petit Glane and Arbogne (uncalibrated model):

RhiresD, default dataset

RhiresD + Payerne station data for Arbogne and and Petit Glane

RhiresD + Avenches station data for Arbogne and Chables station data for Petit Glane

RhiresD + Payerne station data for Arbogne and Chables station data for Petit Glane



	KGE	NSE	pbias
A_A	0.62	0.51	33.4
B_P	0.58	0.64	1
F_A	0.6	0.7	5
P_G	0.64	0.65	12.8

	KGE	NSE	pbias
A_A	0.63	0.55	2.6
B_P	0.58	0.64	0.9
F_A	0.6	0.7	5
P_G	0.5	0.56	-7.2

	KGE	NSE	pbias
A_A	0.62	0.45	29.8
B_P	0.58	0.64	0.9
F_A	0.6	0.7	5
P_G	0.67	65	8.8

	KGE	NSE	pbias
A_A	0.63	0.55	2.6
B_P	0.58	0.64	0.9
F_A	0.6	0.7	5
P_G	0.67	65	8.8

A_A = Arbogne (Avenches), B_P = Broye (Payerne), F_A = Flon aval (Oron), P_G = Petit Glane (Cugy)

Figure S5. Different Combinations of the RhiresD and stationdata for the subcatchment Petit Glâne and Arbogne

data for the Petit Glâne yielded the best model fit and lowest percentage bias. The newly aggregates timeseries of RhiresD gridded data and the two station timeseries are made available here: https://doi.org/10.5281/zenodo.17243147 (Heinz, 2025).

References

Brunner, M. I., Bjornsen Gurung, A., Zappa, M., Zekollari, H., Farinotti, D., and Stahli, M.: Present and future water scarcity in Switzerland: Potential for alleviation through reservoirs and lakes, Sci Total Environ, 666, 1033–1047, https://doi.org/10.1016/j.scitotenv.2019.02.169, brunner, Manuela I Bjornsen Gurung, Astrid Zappa, Massimiliano Zekollari, Harry Farinotti, Daniel Stahli, Manfred eng Netherlands 2019/04/12 Sci Total Environ. 2019 May 20;666:1033-1047. doi: 10.1016/j.scitotenv.2019.02.169. Epub 2019 Feb 17., 2019.

Heinz, M.: Precipitation input file aggregated from RhiresD and stationdata for the Broye catchment, https://doi.org/10.5281/zenodo.17243147, 2025.

Lehning, M., Völksch, I., Gustafsson, D., Nguyen, T. A., Stähli, M., and Zappa, M.: ALPINE3D: a detailed model of mountain surface processes and its application to snow hydrology, Hydrological Processes, 20, 2111–2128, https://doi.org/10.1002/hyp.6204, 2006.

MeteoSwiss: Daily Precipitation (final analysis): RhiresD, 2021.

MeteoSwiss: Combiprecip (CPC), https://opendatadocs.meteoswiss.ch/d-radar-data/d1-precipitation-radar-products, 2025a.

MeteoSwiss: Climate stations - Homogeneous data series, https://opendatadocs.meteoswiss.ch/c-climate-data/c1-climate-stations_homogeneous, 2025b.

MeteoSwiss, F. O. o. M. and Climatology: Daily Precipitation Ensemble: RhydchprobD, 2019.

Michel, A., Schaefli, B., Wever, N., Zekollari, H., Lehning, M., and Huwald, H.: Future water temperature of rivers in Switzerland under climate change investigated with physics-based models, Hydrology and Earth System Sciences, 26, 1063–1087, https://doi.org/10.5194/hess-26-1063-2022, 2022.

Muelchi, R., Rössler, O., Schwanbeck, J., Weingartner, R., and Martius, O.: An ensemble of daily simulated runoff data (1981–2099) under climate change conditions for 93 catchments in Switzerland (Hydro-CH2018-Runoff ensemble), Geoscience Data Journal, 9, 46–57, https://doi.org/10.1002/gdj3.117, 2021.

Viviroli, D., Zappa, M., Gurtz, J., and Weingartner, R.: An introduction to the hydrological modelling system PREVAH and its pre- and post-processing-tools, Environmental Modelling & Software, 24, 1209–1222, https://doi.org/10.1016/j.envsoft.2009.04.001, 2009.

Zarrineh, N., Abbaspour, K., Van Griensven, A., Jeangros, B., and Holzkämper, A.: Model-Based Evaluation of Land Management Strategies with Regard to Multiple Ecosystem Services, Sustainability, 10, https://doi.org/10.3390/su10113844, 2018.