Influence of morphology and land use in multi-basin calibration of conceptual TUW model

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ABSTRACT

The rainfall-runoff modeling over the whole area of Austria is a challenging task. In our paper, we select the HBV type conceptual rainfall-runoff model TUW. There are many factors that can influence the model outputs. The model structure, quality of the input data, setup of the objective function, parameter ranges, etc. In the study, our goal was to detect which characteristics and their spatial distribution influence the efficiency of a conceptual rainfall-runoff model efficiency most in Austria. We can find catchments with various geomorphology, land use, elevation, etc. For calibration we select the two types of the TUW model; the lumped and semi-distributed versions. Firstly, we try to select the structure of the TUW model which is more suitable for these types of catchments. Finally, we test the model performance in the validation. The efficiency of the models based on lumped and spatially distributed inputs was compared. The question as to how the morphology and land use affects the model´s performance was targeted; we find out that the semi-distributed version can provide more reliable results than lumped version.

1 Methods

- In our work we used the conceptual lumped and semi-distributed HBV type model TUW
- The model consists of three modules that represent snow accumulation and melting, root zone soil moisture changes, and runoff generation and routing

Calibration strategy:

- The TUW model was calibrated for period 1991-2000
- Then was validated for period 2014-2017
- We use an automatic calibration procedure using a differential evolution algorithm (Ardia et al., 2015)
- Objective function (OF) combines Nash-Sutcliffe coeficient (NSE) estimated from normal and logaritmic transformed (log NSE) daily streamflow values:
- $\mathrm{RME} = \frac{1-NSE}{2} + \frac{1-logNSE}{2}$
- $\mathrm{NSE} = 1 - \frac{\sum_{i=1}^{1}(Q_{sim,i}-Q_{obs,i})^2}{\sum_{i=1}^{1}(Q_{obs,i}-\overline{Q}_{obs})^2}$
- $\mathrm{logNSE} = 1 - \frac{\sum_{i=1}^{1}\left(\log(Q_{sim,i})-\log(Q_{obs,i})\right)^2}{\sum_{i=1}^{1}\left(\log(Q_{obs,i})-\log(\overline{Q}_{obs})\right)^2}$

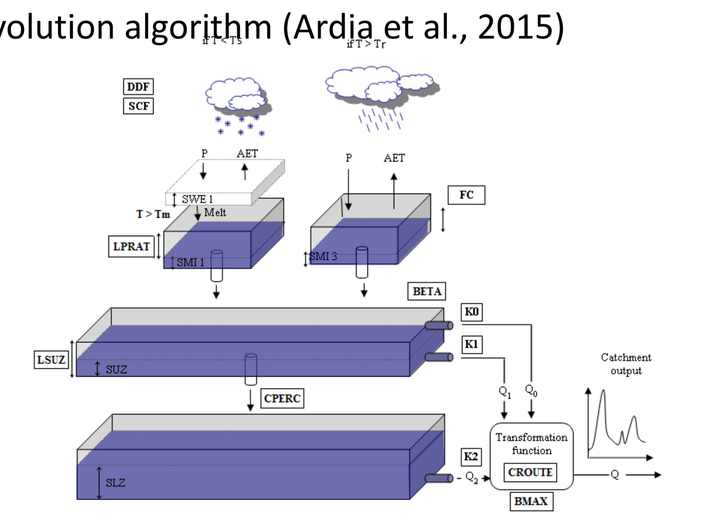

Fig. 1: Structure of the TUW model.

2 Input data

- 180 Austrian catchments, with Spartacus data (Hiebl, et al. 2016) derived to hypsometric zones (200 m), dividied in the two groups Alpine and Lowland
- Input data (1991-2000) Precipitation, Observed Flow, Air temperature and Potential evapotranspiration (Blaney Cridlle)
- The catchment areas varied from 14.2 km^2 to 6214 km^2

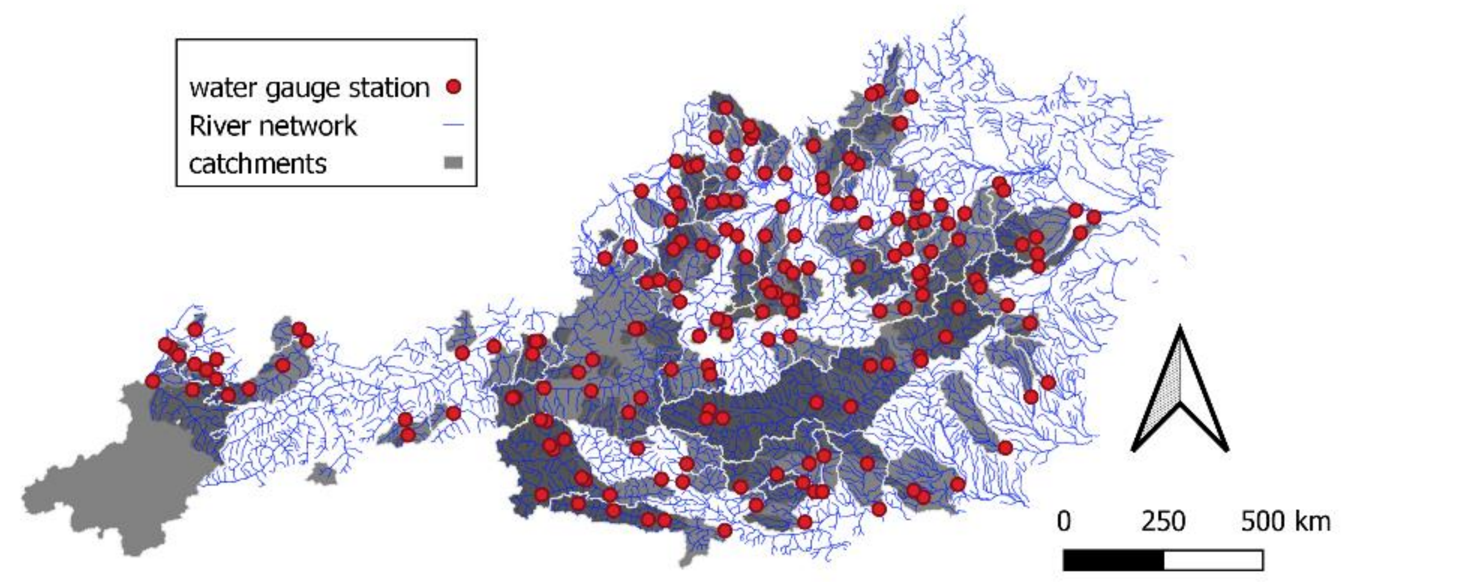

Fig. 2: Location of the selected 180 Austrian catchments

3 Results

RME range	Median values RME [-]	Slope (SL) [%]	Forest cover (FP) [%]	Agricultural land (AP) [%]
0.00-0.71	0.68	8.53	44.63	29.57
0.72-0.75	0.74	13.51	66.06	16.88
0.75-0.78	0.77	14.48	57.61	26.40
0.78-0.81	0.80	22.53	51.86	14.02
0.82-0.85	0.83	26.46	46.20	11.50
0.86-0.93	0.88	31.13	36.19	7.62

Table 1. RME of the TUW semi-distributed model for 180 Austrian catchments, divided into 6 groups by the RME range, with a median of the catchments characteristics: Slope of the terrain (SL), Forest cover percentage (FP), and Agricultural lands percentage (AP)

RME range	Median values RME [-]	Slope (SL) [%]	Forest cover (FP) [%]	Agricultural land (AP) [%]
0.00-0.51	0.36	18.19	54.69	14.19
0.52-0.61	0.57	18.21	52.73	21.45
0.61-0.65	0.63	18.58	45.81	20.28
0.65-0.69	0.67	18.02	50.19	15.37
0.69-0.74	0.71	23.77	47.70	9.84
0.74-0.88	0.77	28.26	42.14	10.74

Table 2. RME of the TUW lumped model for 180 Austrian catchments, divided into 6 groups by the RME range, with a median of the catchments characteristics: Slope of the terrain (SL), Forest cover percentage (FP), and Agricultural lands percentage (AP)

RME range	Median values RME [-]	Slope (SL) [%]	Forest cover (FP) [%]	Agricultural land (AP) [%]
0.32-0.59	0.52	6.67	49.34	42.66
0.60-0.65	0.62	18.50	63.31	19.70
0.65-0.70	0.68	10.87	50.93	26.67
0.70-0.77	0.73	19.63	47.78	12.15
0.78-0.83	0.8	26.85	45.25	9.47
0.83-0.94	0.88	34.60	32.59	6.47

Table 3. *Validation RME of the TUW semi-distributed model for 180 Austrian catchments, divided into 6 groups by the RME range, with a median of the catchments characteristics: Slope of the terrain (SL), Forest cover percentage (FP), and Agricultural lands percentage (AP)*

RME range	Median values RME [-]	Slope (SL) [%]	Forest cover (FP) [%]	Agricultural land (AP) [%]
0.22-0.46	0.41	15.55	42.57	19.75
0.47-0.59	0.55	19.30	63.06	18.18
0.59-0.62	0.61	16.84	45.53	17.65
0.63-0.65	0.64	13.12	46.53	34.94
0.66-0.70	0.68	22.88	45.77	9.84
0.71-0.89	0.75	17.04	38.71	11.40

Table 4. *Validation RME of the TUW lumped model for 180 Austrian catchments, divided into 6 groups by the RME range, with a median of the catchments characteristics: Slope of the terrain (SL), Forest cover percentage (FP), and Agricultural lands percentage (AP)*

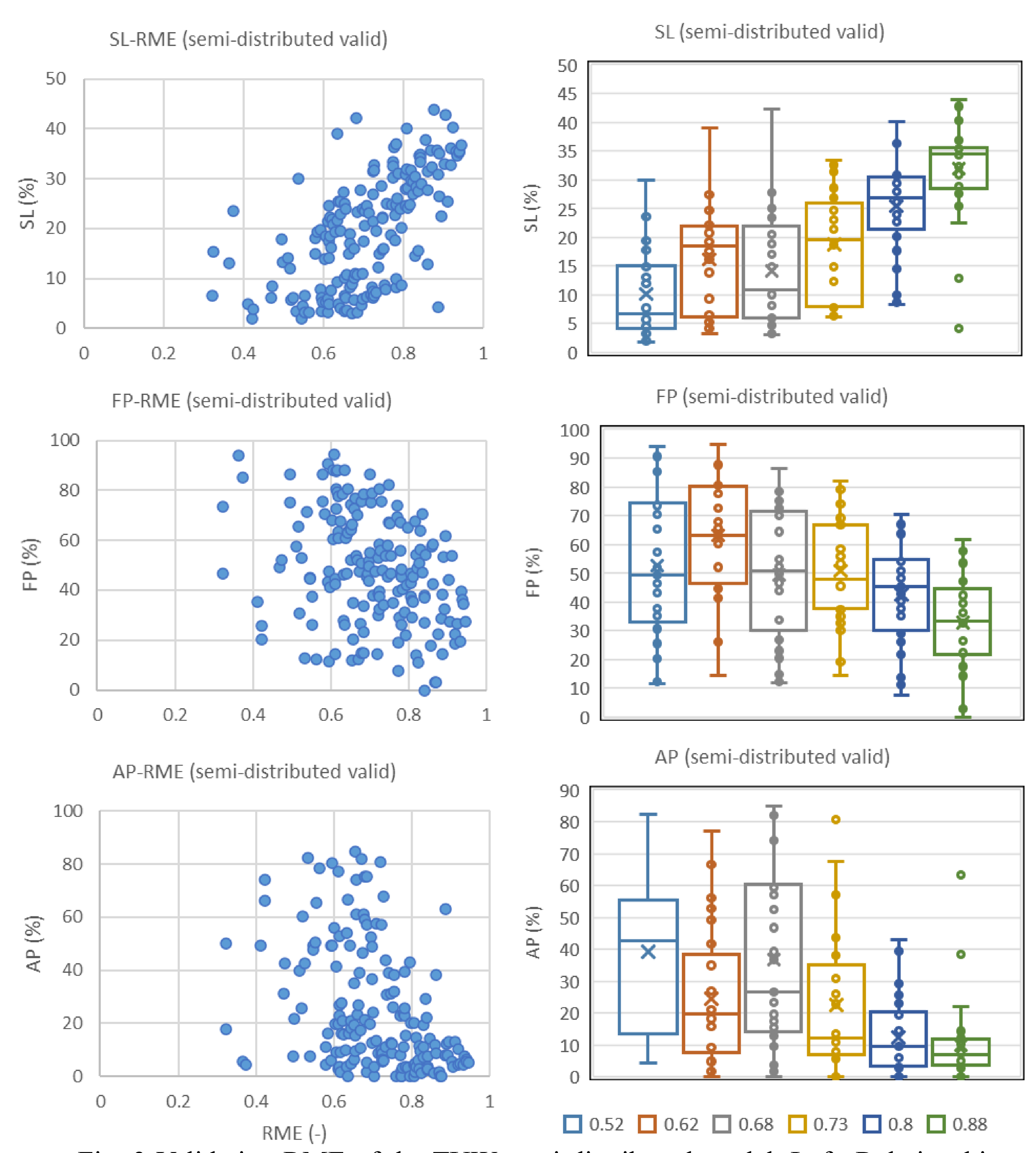

Fig. 3 Validation RME of the TUW semi-distributed model. Left: Relationships between characteristics of the catchments and validation RME for 180 Austrian catchments. Right:Boxplots for the groups by the RME (from lowest RME - blue to best RME - green) and characteristics of the catchments: where SL – is the slope of the terrain, FP – the percentage of the forest cover, AP – the percentage of the agricultural land.

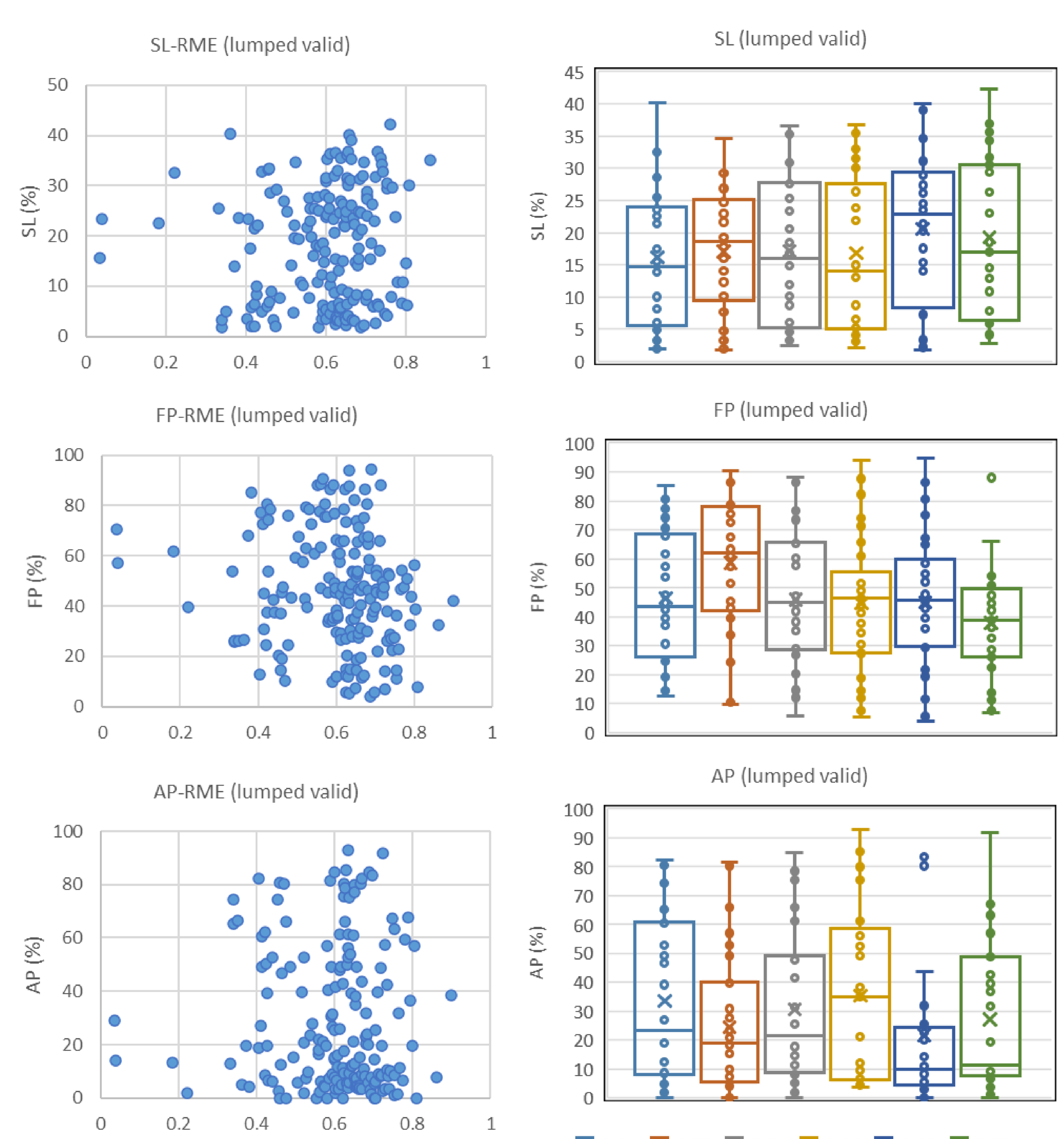

Fig. 4 Validation RME of the TUW lumped model. Left: Relationships between characteristics of the catchments and validation RME for 180 Austrian catchments. Right: Boxplots for the groups by the RME (from lowest RME - blue to best RME - green) and characteristics of the catchments: where SL - the slope of the terrain, FP – the percentage of the forest cover, AP – the percentage of the agricultural land.

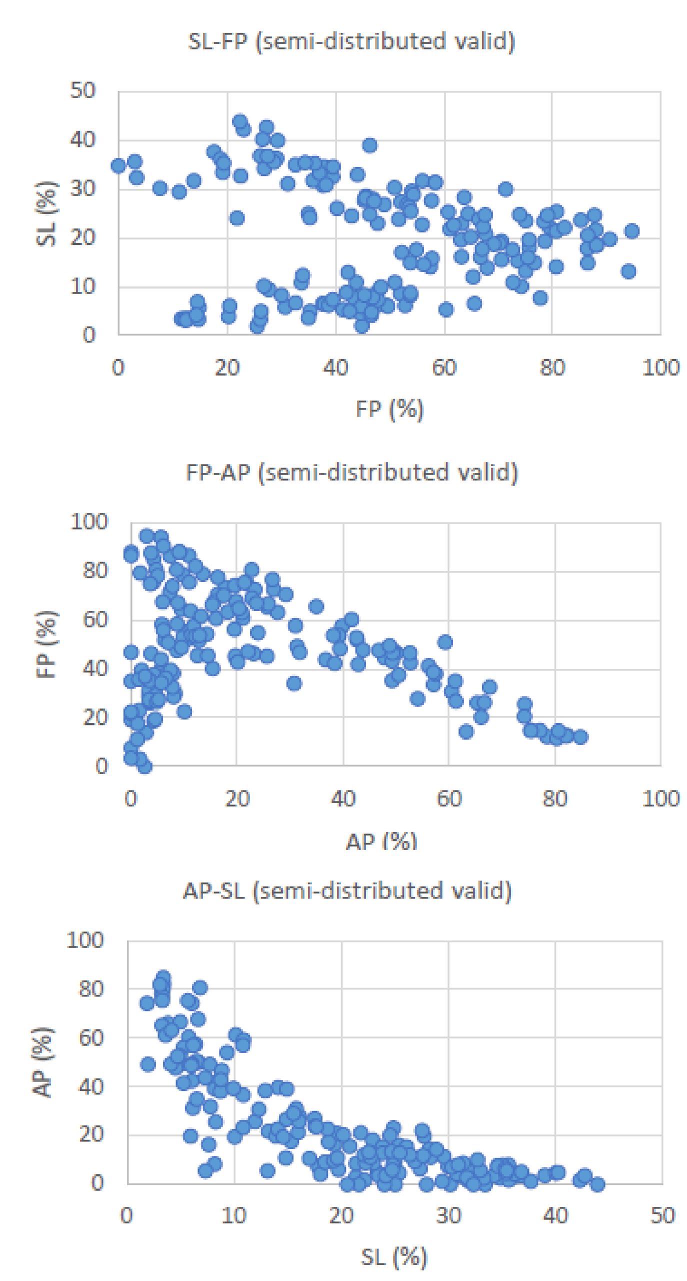

Fig. 5 Dependency between selected catchments characteristics, for 180 Austrian catchments, SL-FP (top), FP-AP (middle), and AP-SL (bottom)

4 Discussion

We try to find the connection between catchment characteristics like morphology and land use and runoff model efficiency. For representing morphology, we select the slope of the terrain (SL), and for the land use, we select the percentage of the forest cover (FP), and the percentage of the agricultural lands (AP). The runoff model efficiency was estimated with RME = (NSE + log NSE)/2. Secondly, we sort the RME data from the lowest to the highest value and split it into 6 groups (each group has 30 catchments), then we make the graphic and median comparison for each group characteristics SL, FP, and AP. The results show a clear dependency between selected characteristics and the RME in the semi-distributed version. The highest dependency was between RME and the SL. In both graphical comparisons of median characteristics, we detected that the groups of the catchments with higher slope of the terrain perform better in RME. The semi-distributed model has great efficiency in mountainous areas without high percentage of forest cover and shallow soil beds, where the rainfall contributed to the surface runoff or runoff from shallow soil bed. In the case of the lumped version, there was no clear dependency between RME and catchments characteristics.

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