Effects of model input data uncertainty in simulating water resources of a transnational catchment

C. Camargos[1], S. Julich[2], M. Bach[1], L. Breuer[1]

[1]Institute for Landscape Ecology and Resources Management (ILR), Research Centre for BioSystems, Land Use and Nutrition (iFZ), Justus Liebig University Giessen, Giessen, Germany
[2]Department for Soil Science and Site Ecology, Technische Universität Dresden, Tharandt, Germany

I. Motivation and Objectives

Landscapes consist of different ecosystem components and how these components affect water quantity and quality need to be understood. The most widely used tool to investigate these aspects in rural areas is the partly-deterministic Soil and Water Assessment Tool (SWAT). Despite its wide application, it is still debated if complex models such as SWAT are properly used. Many sources of error exist, such as input and validation data, model structure and parameters. All these sources contribute to the global uncertainty of models. This study focuses on the investigation of the impact of spatial input data uncertainty on water resources simulations for the Haute-Sûre catchment. Thus, we are interested in evaluating the model efficiency and parameters uncertainty according to different model resolutions.

II. Study area: Haute-Sûre Catchment

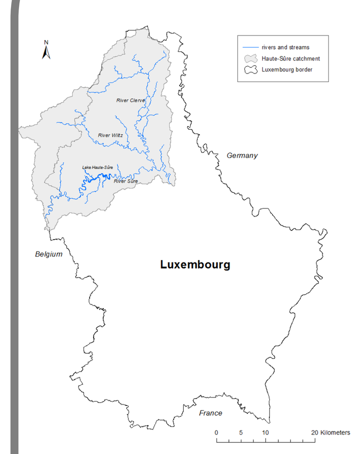


Figure 1: Haute-Sûre catchment location

Partly located in the north of Luxembourg and partly in the southeast of Belgium, the Haute-Sûre catchment is about 943 km². As part of the catchment, the Haute-Sûre Lake is an important source of drinking water for the Luxembourg population, satisfying 30% of the city's demand. According to the Corine Land Cover classification of 2006, the catchment is covered by 44% of complex agricultural land use, 42% of forests (broad-leaves, coniferous and mixed), 10% of pasture and 4% of urban area. The soils are mainly Cambisoil (87%) and Leptosoil (13%) that can be separated in different groups based on soil parent material. Altitude ranges from 214 to 568 meters above mean sea level.

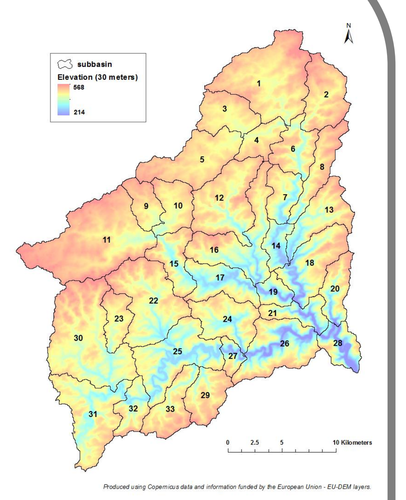


Figure 2: Subbasins and 30 meter resolution DEM

III. Methodology

We applied the SWAT model for the period of 2006 to 2012 and used a variety of digital information on soils, elevation and land uses with spatial resolutions of 30, 60 and 90 meters. Next, we delineated the watershed, subbasins and reach network for the 30 meters resolution project (30 m) and used the same shapefiles to create 60 and 90 meters resolution projects (respectively, 60 m and 90 m).
SWAT was forced by daily climate data from stations inside the catchment: nine stations for precipitation, relative humidity and minimum and maximum temperature, four stations for solar radiation and two station for wind speed. Evapotranspiration was calculated by the Hargreaves method and, for the areas of agriculture cultivation, we adopt a crop rotation of winter wheat - winter wheat - corn.
SWAT was calibrated using discharge data from the main watershed outlet point. For the parameters shown in table 1, a latin hypercube approach was used to sample a set of 1000 parameters with a pre-defined parameter uncertainty bound.

Parameter name	Parameter definition	Parameter factor	Lower bound	Upper bound	Units
SURLAG18	Surface runoff lag coefficient	replace	0	3	days
SFTMP	Snowfall temperature	replace	-2	0.5	°C
SMTMP	Snow melt base temperature	replace	0	2	°C
TIMP	Snow pack temperature lag factor	replace	0	1	-
AWC	Available water capacity of the soil layer	multiple	-15%	15%	mm/mm
CHN	Hydraulic conductivity of channel	replace	0.01	0.3	mm/h
CHK	Roughness coefficient n	replace	0.01	30	mm/h
k_norock	Saturated hydraulic conductivity	multiple	-15%	15%	mm/h
ALPHA_BF	Baseflow alpha factor	replace	0.001	0.99	-
GW_DELAY	Groundwater delay time	replace	0	31	days
GW_REVAP	Groundwater revap coeficient	replace	0.02	0.2	-
GW_QMN	Threshold water level in shallow aquifer	replace	0	100	mm H_2O

Table 1: SWAT parameter description, lower and upper bound

IV. Results

HRUs analysis

Areas with the same soil type, land use and slope form an Hydrologic Response Unit (HRU), the basic unit where the loadings are calculated. Thus, the projects are different only in the HRU level. Regarding the number of HRUs, project 30 m has 1379, project 60 m has 1293 and project 90 m has 1214.
Figure 3 shows that land use and soil distribution do not significantly change when the resolution varies from 30 to 90 meters. However, the slopes get smoother at the same time that the resolution decreases.

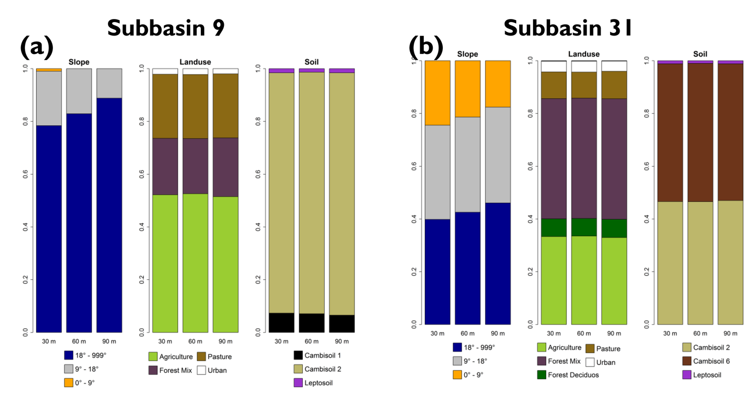


Figure 3: Percentage of HRUs area distribution in subbasin (a) 9 and (b) 31

Discharge (output) analysis

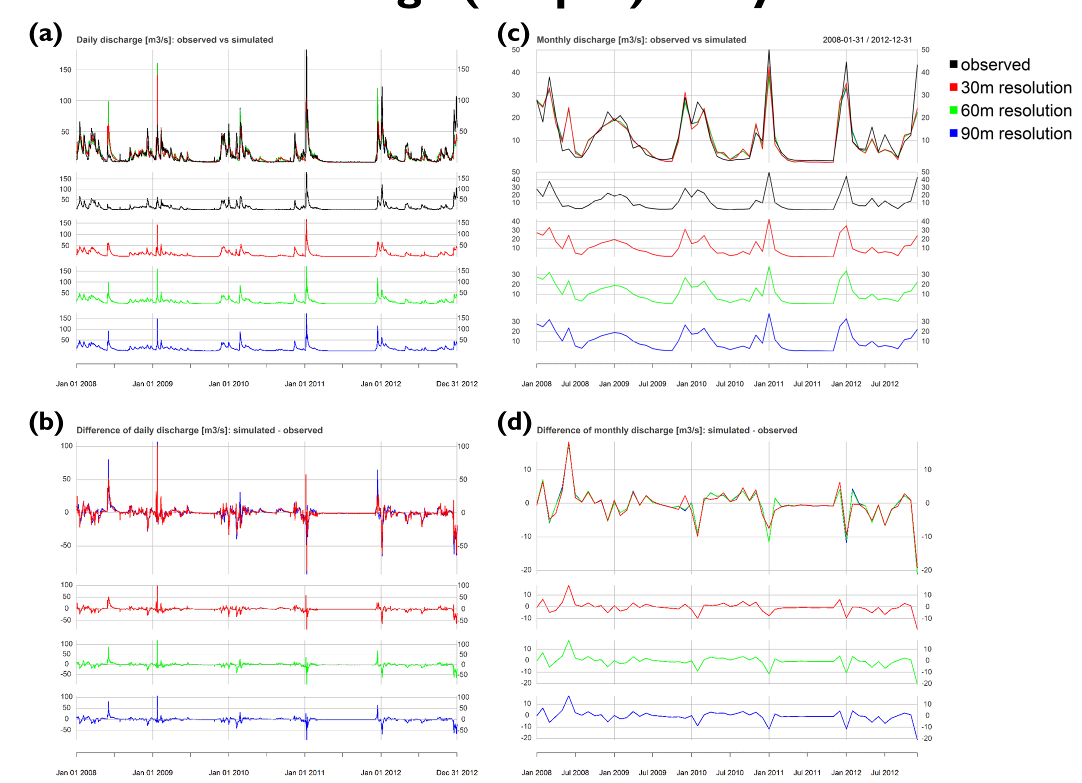
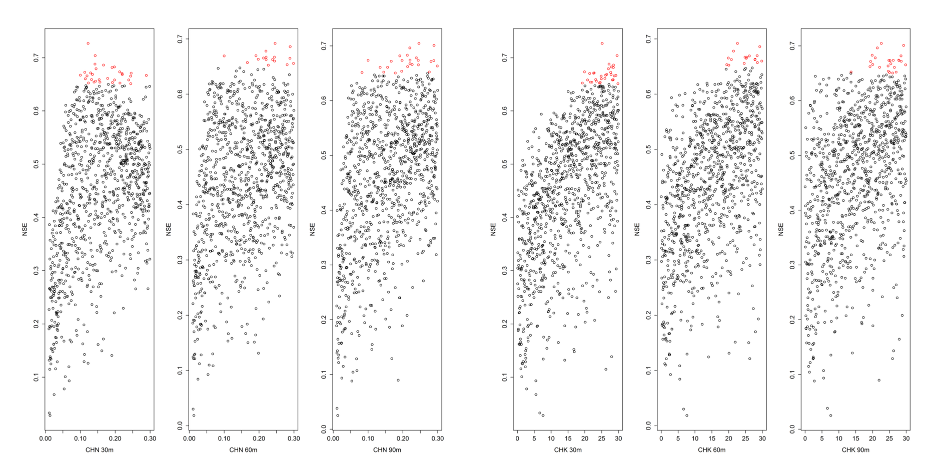


Figure 4: Mean (a) daily and (c) monthly discharge. Difference between simulated and observed (b) daily and (d) monthly discharge data.

	Resolution	NSE	P Bias
Daily	30 meters	0.73	-4.2
	60 meters	0.69	-3.8
	90 meters	0.70	-3.8
Monthly	30 meters	0.84	-4.2
	60 meters	0.82	-3.6
	90 meters	0.82	-3.6

Table 2: Error measurements according to different resolutions.

Parameters analysis



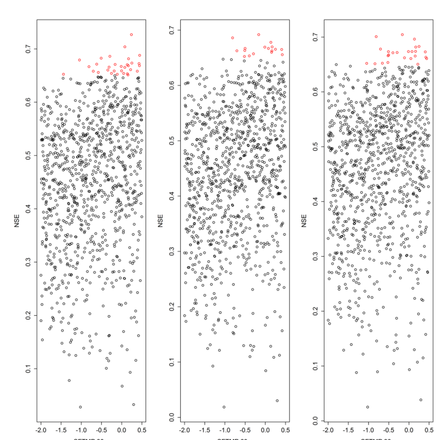


Figure 5: Dotty plots of NSE and the set of parameters, using a threshold of 0.65 for NSE.

CHN	Resolution	Minimum	Maximum	Interval
	30m	0.100	0.289	0.189
	60m	0.100	0.299	0.199
	90m	0.083	0.299	0.216

CHK	Resolution	Minimum	Maximum	Interval
	30m	19.267	29.830	10.563
	60m	19.423	29.830	10.408
	90m	13.644	29.830	16.187

SFTMP	Resolution	Minimum	Maximum	Interval
	30m	-1.442	0.445	1.887
	60m	-0.810	0.420	1.230
	90m	-1.045	0.439	1.484

Table 3: Differences among parameters that generate the best model fits.

V. Discussions and Conclusions

- The changes of resolution only marginally affect SWAT model efficiency when dealing with discharge. So, in terms of water quantity, the user may opt for the lower resolution (90 meters).
- However, looking closer to HRU level, decreasing the resolution make the slopes smoother what may affect the surface runoff, and consequently, impact the erosion and sediment transport calculation.
- When comparing the goodness-of-fit criteria and parameter values, many parameters are distributed at the entire range. We could notice a constrained behavior only for parameters SFTMP, CHN and CHK, showing the model sensitivity to this parameters.
- Analyzing different resolutions, the uncertainty of parameter CHN decreases for higher resolution however the uncertainty of parameter SFTMP decreases for lower resolution. Further analysis are necessary in an attempt to identify more general patterns.

VI. Future research

- Including new maps with lower resolution to determine the threshold where information gets lost.
- Analyze also water quality as output of the model.
- Decrease the number of parameters used for calibration, focus on the most sensitive ones.

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Contact
Camargos.S.Carla@umwelt.uni-giessen.de