Appendix 1 - SWAT model input data and performance

A1.1 - Input Data

- Spatial domain: Middle Mulde River Basin (1611 km²)

- Weather data

  - Raw data: time series of measured daily precipitation, solar radiation, minimum and maximum temperature, wind speed, and relative humidity for DWD weather and precipitation stations in period 1980-2014
  - Processed data: Regionalized weather data using Thiessen polygons, precipitation was corrected for measurement errors according to (Richter 1995)

- Digital elevation model (DEM)
  - ATKIS-DGM25 (25 m resolution raster map)

- Land use

  - Raw data: ATKIS Basis DLM provided by the Federal Agency for Cartography and Geodesy (BKG) for the year 2010; Corine Land Cover data provided by the European Environment Agency (EEA) for the year 2012, Color-infrared (CIR)-based biotope and land-use map provided by the Saxon State Agency for Environment, Agriculture, and Geology (LfULG) for the year 2005
  - Processed data: Raster map (25 m resolution) based on ATKIS Basis DLM, refined for type of forest (mixed, deciduous, coniferous) based on Corine and type of grassland (intensive or extensive) based on the CIR biotope and land-use map

- Soil

  - Raw data: BK50 digital soil map for the state of Saxony provided by LfULG for the year 2012, including a soil property database
  - Processed data: to obtain soil parameters not included in the databases we used pedotransfer functions provided by the Ad-hoc-Arbeitsgruppe Boden (2005)
  - The final database includes the hydrologic soil type, maximum rooting depth and layer specific depth, texture, organic carbon content, bulk density, available water capacity, saturated hydraulic conductivity, USLE C factors

- Land management
    - Spatio-temporal crop management data (crop rotations for different farm types including specification (type, amount, date) of tillage, fertilizer, planting and harvest operations as typical for soil-climatic regions in Central Germany (Witing et al. 2014)
    - Crop share and yield statistics 1991-2012 for municipalities (Landkreise)
    - To estimate agricultural gross margins we obtained crop-specific market prices and variable production costs from the Association for Technology and Structures in Agriculture (KTBL) (accessed in 2017)
- Hydrological data
    - Measured discharge (daily) and water quality (e.g. N and P species, bi-weekly to monthly) for different gauging stations and varying time periods
    - Point sources: average nutrient loads from waste water treatment plants

A1.2 – Calibration and performance of the SWAT model

For the Middle Mulde Basin, SWAT was calibrated against daily streamflow and monthly loads of sediment as well as nitrogen and phosphorus fractions at three gauges (Bad Düben, Golzern and Erlln), taking into account four performance metrics (Nash-Sutcliff-Efficiency – NSE, relative index of agreement – rd, Kling-Gupta-Efficiency – KGE and percentage bias – PBIAS). We used the R package 'SWATpasteR' (Schürz et al. 2017) for both sensitivity analysis and model calibration. After sensitivity testing of 130 model parameters which were sampled for 14,076 model simulations using the STAR method (Razavi and Gupta 2016), we carried out further 10,000 Latin-Hypercube sampled SWAT simulations to calibrate the most sensitive 29 model parameters. Table A1 summarizes the performance values of the best model simulation, which we defined as the simulation with the minimum total rank sum of all performance metrics for all variables and gauges.

According to the classification of Moriasi et al. (2015), model performance ranged from satisfactory to very good for daily streamflow and was very good at all gauges for monthly loads of Nitrate-N. For all other variables, model performance was rather unsatisfactory with a few exceptions at single gauges (Tab. A1.1, see also Fig. A1.1).

Moreover, we manually adjusted SWAT plant parameters in order to fit simulated yields of single crop types to the yields observed in period 1995 to 2009 (Fig. A1.1). Our results illustrate the difficulty in identifying a single parameter set that simultaneously satisfies multiple performance criteria for multiple variables at multiple gauges in the Middle Mulde Basin.

However, it nevertheless appears reasonable to use the model for land use change impact assessments regarding crop yield, streamflow, Nitrate-N and sediment loads.

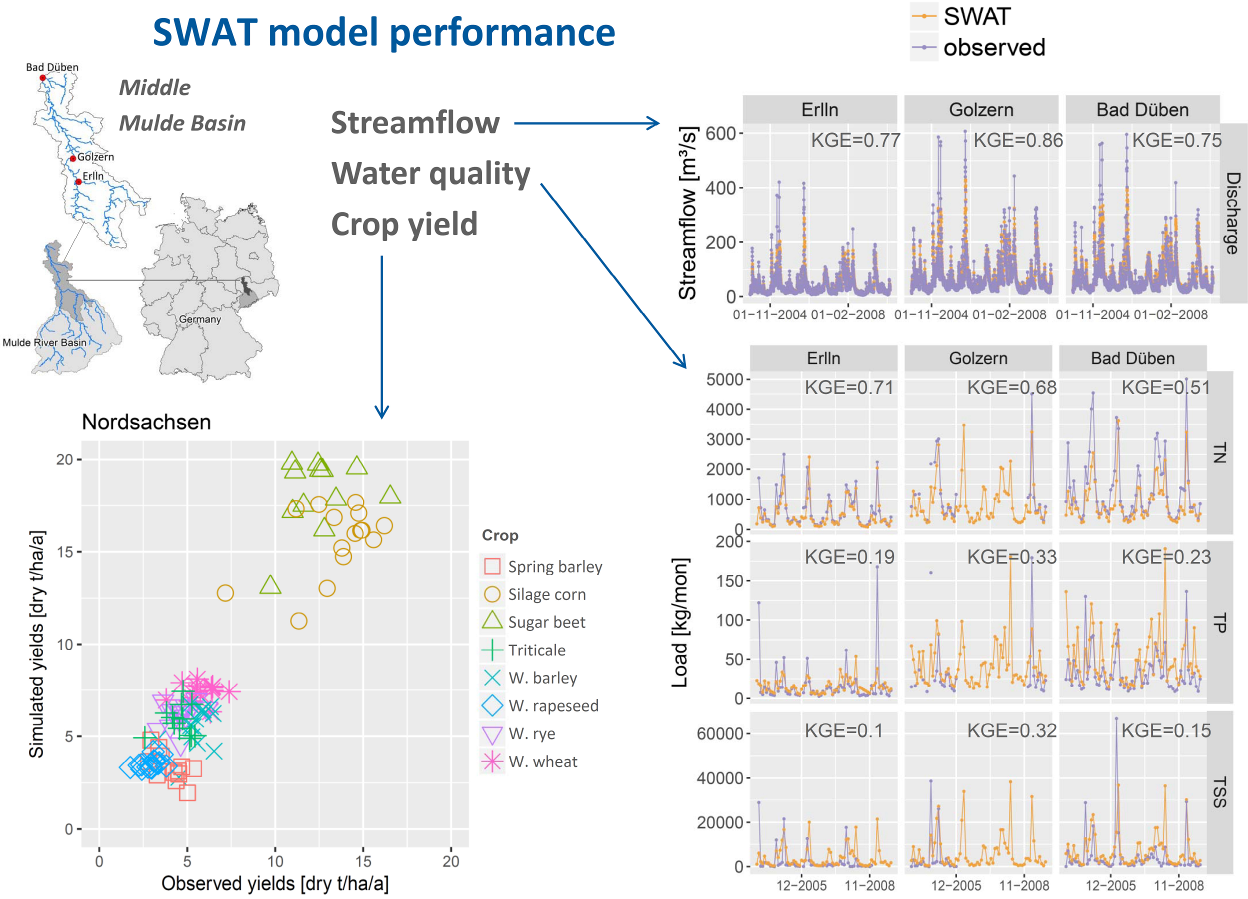

Figure A1.1: SWAT model performance for predicting daily streamflow, monthly water quality and mean annual crop yields the Middle Mulde Basin.

Table A1.1: Performance metrics for the Middle Mulde Basin.

		Calibration (1999-2003)				Validation (2004-2009)			
Variable	**Gauge**	**NSE**	**dr**	**KGE**	**PBIAS**	**NSE**	**dr**	**KGE**	**PBIAS**
Daily streamflow	Bad Düben	0.66	0.97	0.73	15.7	0.69	0.94	0.75	20.3
	Golzern	0.87	0.99	0.87	9.6	0.86	0.97	0.86	10.3
	Erlln	0.74	0.98	0.76	6.8	0.66	0.96	0.77	11.5
Monthly Nitrate-N load	Bad Düben	0.71	0.95	0.64	-29.4	0.72	0.95	0.63	-21.6
	Golzern	0.76	0.96	0.72	-25.9	0.82	0.97	0.72	-19.1
	Erlln	0.7	0.97	0.7	-25.9	0.74	0.97	0.8	-15.2
Monthly Nitrite-N load	Bad Düben	-4.57	0.37	-1.01	141.9	-5.33	-0.01	-1.42	218.9
	Golzern	-2.41	-0.1	-0.51	103	-8.28	-3.46	-1.06	192.9
	Erlln	-0.94	-0.61	-0.09	83.5	-7.15	-1.47	-0.95	177.2
Monthly Ammonium-N load	Bad Düben	0.66	-1.66	0.66	31.6	0.37	0.61	0.38	59.3
	Golzern	0.29	-6	0.48	43.8	0.4	-19.09	0.2	74.4
	Erlln	0.67	-1.77	0.65	24.9	0.18	-9	0.11	74.9
Monthly organic N load	Bad Düben	-0.87	0.65	-0.07	-78	-0.96	0.65	-0.09	-77.6
	Golzern	0.08	0.83	0.07	-62	0.13	0.7	0.22	-49.3
	Erlln	0.35	-1.59	0.28	-50.4	0.23	0.48	0.19	-46.2
Monthly mineral P load	Bad Düben	-2.85	0.62	-0.83	133.9	-15.05	-1.09	-1.95	251.5
	Golzern	-0.45	0.85	-0.13	72.5	-6.42	-0.16	-0.31	104.7
	Erlln	0.54	-1.39	0.45	49.7	-2.08	-1.35	-0.16	107.9
Monthly organic P load	Bad Düben	0.04	0.84	-0.02	-67.3	-0.17	0.7	0.14	-55.4
	Golzern	0.53	0.93	0.25	-48.4	0.21	0.13	0.15	-25.1
	Erlln	0.7	0.92	0.7	-26.4	0.08	0.92	-0.09	-52.2
Monthly sediment load	Bad Düben	0.05	-7.46	0.46	33.4	0.08	-14.97	0.15	67.4
	Golzern	0.72	-1.61	0.53	-15.7	0.29	-14.96	0.31	51.1
	Erlln	-4.02	-1.77	-2.02	244.4	-0.04	-22.48	0.08	73.1

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