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EVALUATION OF A DISCHARGE-SEDIMENT HYSTERESIS MODEL TO CALCULATE CATCHMENT SEDIMENT LOAD

ABSTRACT

Water quality data typically show a (mostly clockwise) discharge-sediment hysteresis loop which is usually not taken into account in load estimation techniques. In this study, we investigated a simple empirical model to describe the hysteresis using discharge measurements of the Petzenkirchen watershed (65 ha), Austria. The model was calibrated against continuous turbidity measurements on a storm event basis. The model was able to reproduce important dynamics such as loops within the main hysteresis loop that are caused by multiple discharge peaks. However, the calibrated model parameters changed for the different storms investigated, indicating time-variant shapes and magnitudes of the hysteresis loops. Before the model can be applied practically we still need to investigate the mechanisms behind the variable hysteretic behaviour by looking for relationships between the single event model parameters and event characteristics. Additionally, the model needs to be evaluated within an uncertainty estimation framework that accounts for model and data uncertainties.

CATCHMENT CHARACTERISTICS

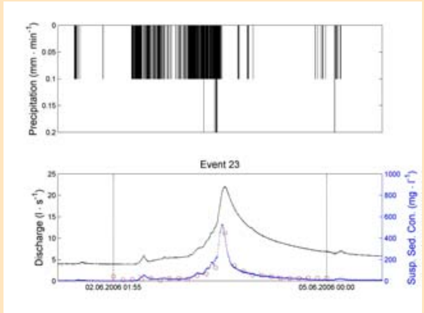
size (ha):	66	highest observed flow ($l \cdot s^{-1}$):	>400
mean slope (%):	8	share of agricultural land (%):	92
form factor (width / length):	0.3	mean annual precipitation (mm):	716
river density ($km \cdot km^{-2}$):	0.8	mean annual air temperature (°C):	9.3
mean flow ($l \cdot s^{-1}$):	2		

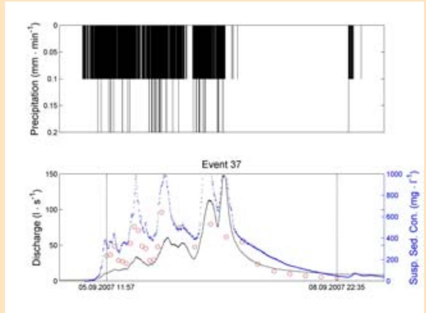
DATA SET

precipitation, discharge, turbidity, (continuous);
sediment concentration (flow proportional grab samples)

METHODOLOGY

Event separation: The start and end of an 'event' was determined according to the sampling times of the flow proportional automatic sampler (o). The black lines show the **discharge** (left y-axis) and the blue curves represent **turbidity** (right y-axis) measurements. On the upper graph precipitation is displayed.

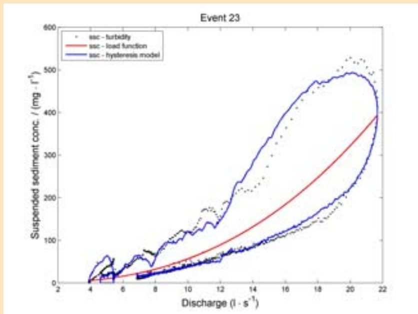


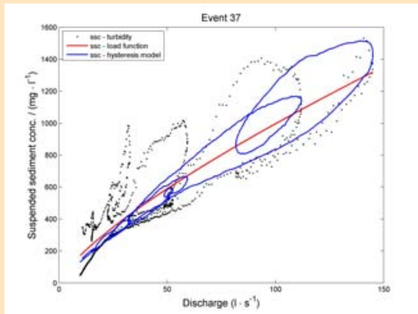


Turbidity models: Both models - **loading function (1)** and **hysteresis model (2)** - were used to simulate suspended sediment concentration for several storm events and obtain different calibration parameters for each event.

$$C_{ss} = a \cdot Q^b \quad (1)$$

$$C_{ss} = a \cdot Q^b + c \cdot \left(\frac{dQ}{dt}\right) \quad (2)$$



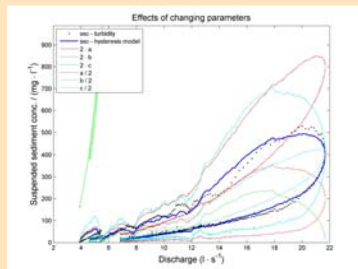


The hysteresis model can be calibrated with higher accuracy than the loading function, but needs three parameters. The parameter values change for each event.

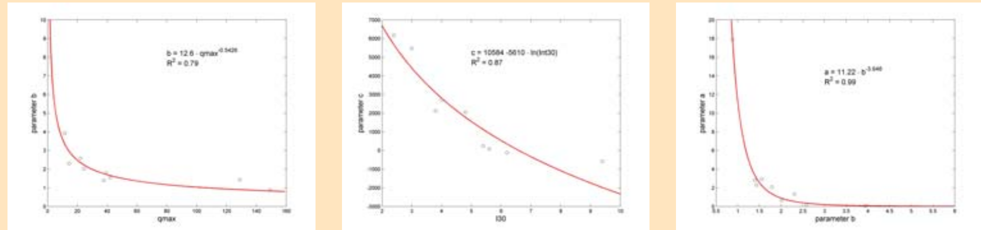
	loading function				hysteresis model				
	a	b	R^2	n	a	b	c	R^2	n
Event 15	0.003	5.047	0.92	1366	0.004	4.983	5254	0.95	1366
Event 20	2.849	1.395	0.40	905	2.817	1.398	5471	0.88	905
Event 23	0.177	2.506	0.75	922	0.142	2.582	2056	0.98	922
Event 27	2.311	1.761	0.76	723	2.107	1.788	2718	0.89	723
Event 28	0.374	2.794	0.50	212	1.336	2.306	6176	0.85	212
Event 29	0.412	2.179	0.71	460	0.667	2.012	2123	0.94	460
Event 30	0.001	5.964	0.74	20	0.059	3.935	89	0.66	20
Event 37	30.619	0.756	0.77	1172	17.887	0.881	241	0.78	1172
Event 40	2.793	1.565	0.92	200	2.929	1.551	-110	0.93	200
Event 41	2.485	1.421	0.86	1781	2.312	1.435	-575	0.88	1781

Effects of changing parameter values:

The accuracy of the model highly depends on parameter b. Small changes of b significantly impact on suspended sediment concentration. Parameter a represents the steepness of the curve and parameter c is influenced by the wideness of the hysteresis loop.



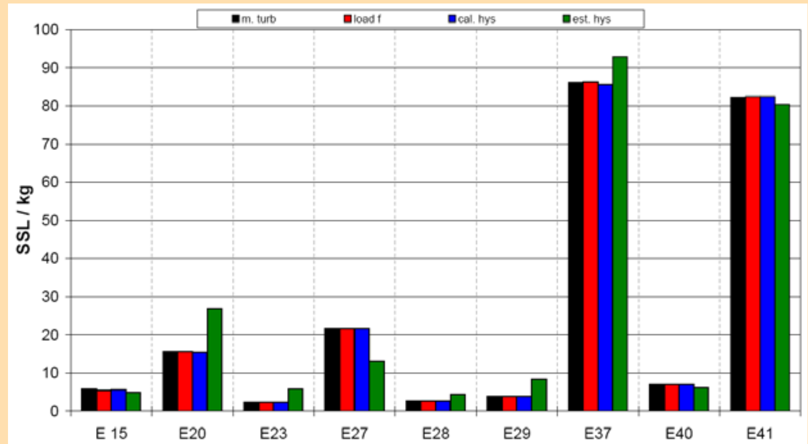
Parameter value estimation: We found a relationship between event characteristics and calibration parameters, with b depending on the maximum event discharge (qmax) and c relating to the maximum rainfall intensity within 30 minutes (I30) . Parameter a strongly correlates with b.



RESULTS

Suspended sediment load (SSL): SSL was calculated with

- measured turbidity - **m. turb.**
- calibrated parameters and load function - **load f**
- calibrated parameters and the hysteresis model - **cal. hys**
- estimated parameters and the hysteresis model - **est. hys**



CONCLUSIONS

For the calculation of SSL the loading function and the hysteresis model practically give the same results as long as event totals are calculated.
With a good data set a relationship between event characteristics and calibration parameters can be found. Once the hysteresis model is calibrated and validated it can be used to calculate turbidity and SSL for single storms using event characteristics (qmax and I30) and discharge (q) as input data.
Nevertheless it is necessary to increase the accuracy of the parameter estimation - probably with combination of more event characteristics and consideration of pre-event conditions (soil water content, SS sources, resuspension, land use).