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Interactive comment on "Contributions of Catchment and In-Stream Processes to Suspended Sediment Transport in a Dominantly Groundwater-Fed Catchment" *by* Yan Liu et al.

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We thank the anonymous reviewer for his/her critical comments helping us to focus on explanations that might be missing.
In the following, the reviewer comments are in normal fonts, whereas our responses are in italic.

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Comments and Responses

The manuscript illustrates a coupled catchment-stream model for water quantity and sediment productions and transport developed for the Ammer River Basin (Germany), which has some important karstic contribution to baseline flow and suspended sediments. The physics- based model that is proposed includes a complex one dimensional hydraulic component for calculating shear stress. Erosion rates are then based on shear stress concepts applied to erosion of bed and bank material (either deposited sediments or consolidate beds), as well as in-stream deposition. The model was developed to tackle Ammer Basin hydrology in particular, however it is proposed as an integrated model of general applicability. The model is built on components of other hydrological and sediment models. It appears to be very focused on in-stream processes. Conversely, sediment sources from land processes (soil erosion) seems too simplified. I have some concerns about the paper and its content.

1. First of all, it is not true that existing models do not account for in-stream processes (P2 L24). For example, I know that SWAT model offers several ways to tackle in-stream sediment transport and erosion, including some physics based approaches based on shear stress and the possibility to include cross section of reaches. Some literature has shown that these SWAT approaches work well. The authors should therefore revise their statements.
Response: The reviewer is right that SWAT has a sediment routine in stream channels for sediment transport. What we meant in the manuscript (P2 L24) is that the models simplify the in-stream processes, such as simplifying the shape of cross sections. HEC-RAS solves the full 1-D St. Venant equation for any type of cross-section including cases with changes in the flow regime. We will sharpen the statement in the revised manuscript.

2. Sediments from urban land is modelled with a well-known wash off/build up ap-

proach. Instead erosion from non-urban areas is tackled with an (to my point of view overly) simplified approach (eqs. 4-6) whose main drivers are runoff and slope. Only one shear stress threshold is considered despite agricultural land diversity, which includes a variety of crops like cereals, vegetables and natural vegetation. This approach does not consider any variability in soil erodibility, or changes in crop cover during the year, which instead impact soil erosion from agricultural land especially among seasons. This flaw limits very much results drawn from the model especially in terms of seasonality and 'hot moments' of erosion.

The soil erosion varies in different croplands. In our studied catchment, the agricultural area is dominated by non-irrigated arable land (80.2 % of the total agricultural area), the crop of which is mainly cereals (largely corn, but the farmers perform crop rotation). We used a simple approach to estimate the average sediment production from agricultural areas without differentiating the crop types. We have the following reasons:

(a) *The Ammer catchment is dominantly groundwater-fed. The stream discharge is too small for the width of the valley due to rerouting of the former head-water catchment in the early Pleistocene. Surface runoff from agricultural areas occurs not very often and is weak, which makes the contribution of agricultural sediment generated by surface runoff rather small compared with contribution of the urban particles. This justifies the simplified approach used for the agricultural areas and a well-known approach for urban areas. The dominance of urban particles in the catchment has been reported by Rügner et al. (2013; 2014) and other studies performed by the same work-group who found a surprisingly high load of persistent organic pollutants in River Ammer, which could be interpreted by the high contribution of urban particles to the total sediment load.*

(b) *To model the variability of soil erosion from different croplands and crop rotation, more information and model parameters are needed. Calibrating the additional parameter sets for different types of croplands would increase the model complexity in an unfeasible manner. We used the same parameterization to estimate the average sediment generation.*

(c) *The crop on the agricultural areas changes from year to year by crop rotation. But the information on the crop rotation is unknown for us, which limits the application of different parameterizations.*

3. I have some concerns about the calibration and validation of the model. The model has 14 calibration parameters and is calibrated vs 1 single station at the outlet of the Basin. I also note that calibrated parameter Ch (Table 2) which regulates the non-urban sediment loads, is lower than its initial range. The risk of over parameterization of this model is very high. Some sensitivity analysis should be shown and discussed as this represent a limit of potential conclusions of the paper. Calibration was driven by a LHS scheme but conducted manually. The authors state that calibration parameter sets were retained to derive 90 % confidence intervals. However these confidence intervals are not shown nor further commented expect for a vague comment at P 11 L 14. The model runs at hourly time step. At what time step calibration and validation were conducted? Water discharge was calibrated for 2013- 2014 and validated for 2015-2016. Sediments were calibrated for 2014 and validated for 2016. Why data for 2015 was not used in this exercise? Data was available as shown in fig 5 but model simulations are not shown. However, model simulations are used for sediment balance considerations e.g. figures 6 and 7. Please explain. The model missed simulation of 2 large rainfall events (one in 2014 and one in 2016), where the highest sediment concentrations occurred. The explanation offered (P11 L 14, p12 L1-2) is that rainfall precipitation measurements 'may be missing'. This should be verified in

the input data. In any case, these 2 events were the most important for sediment load, so all sediment balance is flaw as it cannot consider these main events. It would also be good to see some events in more details given the high temporal discretization of the model.

We used the LHS scheme to calibrate the hydrological model because it runs very fast. But the sediment transport model was calibrated manually due to the high computation time. Therefore, 90 % confidence intervals were calculated for the hydrological model and are shown in Fig. 4 of the manuscript. The models were calibrated and validated to the daily data. The reason for not using data of 2015 for the sediment transport model is that we don't have measurements in 2015. In Fig. 5 of the manuscript, the red dashed line represents measurements and blank solid line indicates model results. The red dash line shows a data gap for year 2015. The model results of 2014 and 2016 were used to compute the sediment balance. Even though the peak suspended sediment concentrations were not well reproduced by the sediment transport model, the model predicted high suspended sediment concentrations for these two events. The attached figure shows three different events with the peak suspended sediment concentration ranging from 200 mg L^{-1} to 1300 mg $^{-1}$. It demonstrates that the sediment transport model in the manuscript has the capability to predict suspended sediment concentrations for different size of events. It is affected very much by the input data such as precipitation, which drives the surface runoff. We will add the figure to the revised manuscript.

4. The results of the model indicate that urban land is the major source of sediments in the catchment. this is possible, but I find hard to believe that 67 % of the basin (agricultural land) contributes almost nothing to sediment loads. Even if runoff production is very low and land is gentle sloping (P 21 Lines 10-12), I would expect more contribution. The authors should check with other lines of evidence (e.g. literature of soil erosion from agricultural land in the region) if their results

are realistic.

Response: In the Ammer catchment, the contribution of sediments from agricultural land is very small for the investigation period (2014-2016). There are several reasons:

(a) *The formation of the Ammer catchment results in a very wide valley and a small river (the Ammer River) due to rerouting of the former head-water catchment in the Pleistocene. The catchment has a large water storage capacity due to the karst and the slope of this catchment is mild. These characteristics make the surface runoff from the agricultural areas very small, thus small sediment production.*

(b) *The infiltration rates of loamy soil and clay loamy soil are 10–20 mm h-1 and 5–10 mm h-1, respectively. But for the Ammer catchment, very few events have precipitation intensity greater than 10 mm h-1 during the simulation period of 2014–2016. Thus, very few and small surface runoff can occur in the agriculture land, which limits sediment generation and transport from agricultural areas to the river channel.*

(c) *We will add the flow duration curve in the supplementary material. It can be seen that only 0.04 per cent of the discharge is greater than 12 m3 s-1 (2-year return period level), totally 3 events for the entire simulation period, which indicates a very small proportion of big events. During big events, it is possible to generate surface runoff in the agricultural areas.*

(d) *The previous study of Rügner et al. (2013) has compared the turbidity measurements of the same event (30. Nov. 2012) for the Ammer catchment and the Steinlach catchment. The two catchments are in the same region and with similar size of catchment area. The population density of the Ammer catchment is* *higher than that of the Steinlach catchment (but in the same order of magnitude). The difference lies in the topography of the catchments. The measurements of that event show that the peak turbidity of the Steinlach River is 7.4 times higher than that of the Ammer River. It indirectly indicates that the sediment generation of agriculture land from the Ammer catchment is much less.*

Fig 8 indicates an increase of sediment sources following a power-law with discharge, which may make sense. However, I wonder if an excess of sediment transport capacity of the stream was considered in the model. This may regulate deposition when sediment sources are very high. I do not see this being considered in the model (but I may be wrong). Please discuss.
Response: The sediment transport capacity is important for bed load transport. For a given discharge, the flow can only transport a limited bed load by rolling, sliding, and hopping, which is regulated by the transport capacity. The bed load material is mainly sand and gravel. But the cohesive sediment transport is different, which is out of the range of applicability of sediment transport functions formulated based on bed load. The transport capacity of cohesive sediments always exceeds supply (Brunner, 2016). The suspended sediment transport of this study belongs to cohesive sediment transport. Therefore, we stole the algorithm for cohesive sediment in HEC-RAS to simulate suspended sediment transport in our matlab model, which is based on shear stress. The previous study also used shear stress related processes to model suspended sediment transport (Li et al., 2008).

5. What data was used to set karstic sediment loads?
Response: The turbidity of ≈3 NTU was observed for the periods without runoff events (base-flow conditions) in the Ammer catchment. The study of Rügner et al. (2013) showed that karst springs in the Ammer catchment contribute to turbidity. Other studies also showed that karst systems can contribute suspended sediments (Bouchaoua et al., 2002; Meus et al., 2013). For the Ammer River,

the subsurface flow through the karst system dominates the river flow in periods without rainfall events. Therefore, the turbidity under base-flow conditions is potentially generated by subsurface flow through the karst matrix. We set a constant suspended sediment concentration to the subsurface flow. The subsurface flow is obtained from the catchment hydrological model. Then the karstic sediment load was calculated by subsurface flow rates and constant suspended sediment concentrations.

6. Section 3.1 should precede model description. The model was built for the Ammer and some important information driving model conceptualization is given in this section, so this should come first. Information about measurement data should be given in this section. Please move P 9 Lines 14-17 and P10 Liens 18-25 to after current P 8 line 14.
   Response: We will revise accordingly in the revised manuscript.

7. please change color of Load urb and load bed in figs 6 and 7 to better distinguish them.
   Response: We will revise accordingly in the revised manuscript.

8. schematic text at P 18-19 lines 12 onward should be given as a table.
   Response: We will revise accordingly in the revised manuscript.

9. reference in the conclusion to events with 2-year return period (P 22 L 2) is surprising. No reference to return period is done before in the manuscript. Given that model failed to simulate two large rainfall events of the region, I find it hard to believe this statement.
   Response: We will give the reference to the return period of events during the simulation period in the conclusion and also will mention that in the section of data source in the revised manuscript. The model does not well capture the peak concentrations of the two events, but the model gives high concentrations (even though not reach the peak concentration of measurements). We provided several

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events with details (Fig. 1 in question 3) to show that the model can predict high suspended sediment concentrations.

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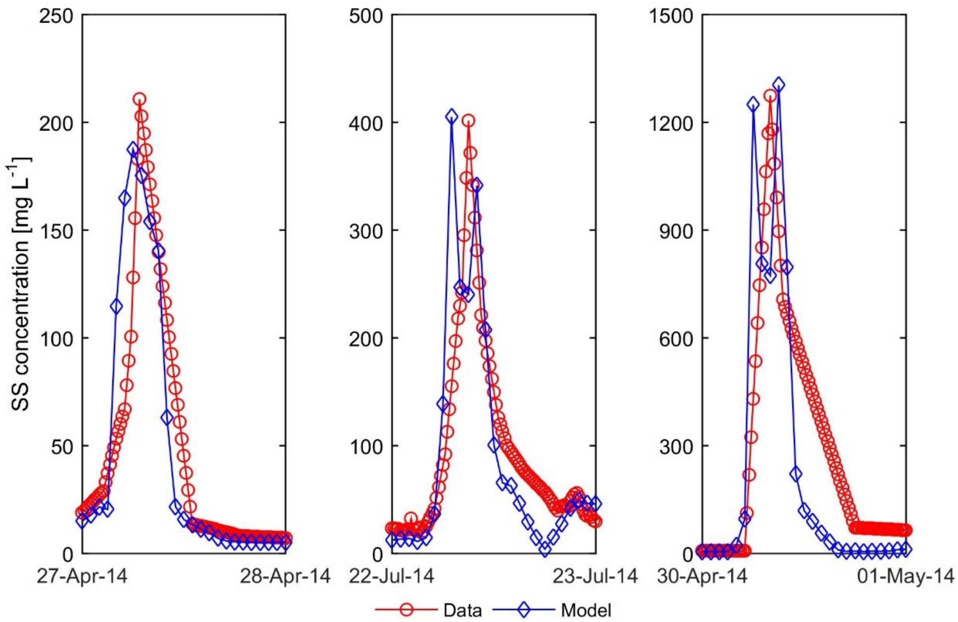

Fig. 1. Measured and modelled suspended sediment concentrations for different events (the event becomes bigger from left to right of the figure)

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