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Hydrology and Earth System Sciences Discussions

Interactive comment on "

Experimental validation of some basic assumptions used in physically based soil erosion models" *by* S. Wirtz et al.

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Thank you for all the comments. In the following section, we will answer all questions and explain the unclear points.

Q: However, the conclusions drawn from this study do not appear warranted. In fact, depending on how the data are analyzed and presented, the opposite conclusions (i.e., shear stress-based equations are adequate for rill erosion modeling) may be drawn

(see specific comments below). The authors can do better in substantiating their conclusions based on the data collected and so strengthen the paper.

A: See answers below.

Q: The title should be more specific to match the focus of the paper.

A: The title has been changed.

Q: The abstract is very concise and can perhaps be expanded to include more details of the experiments, the results, and the conclusions.

A: The abstract has been revised.

Q: Eq. (3) is dimensionally inconsistent. Please check.

A: That's a very interesting point. In fact, the German original version uses the term depth/2, the English translation uses the term depth/width. In the first case, the resulting unit is kg m-2, in the second case kg m-3. The means for resulting in kg m-1 s-2, in the first case the unit m s-2 must be multiplied, the unit of gravitation, in the second case, the unit m^2 s-2 must be multiplied, the unit of gravitation multiplied with the unit of length or width. That means, in the first case, the shear stress is in fact the shear stress per gravitation, in the second case the shear stress per gravitation per width or depth. In the part of the shear stress history, we will not comment this, it is a kind of review where the used equations are shown as they have been published. It is a good example for the physically unclear definitions of the shear stress and this is exactly what we want to show in this chapter.

Q: P 1250, L 9: "Graf (1971) modified this equation...". Which equation is being referred to? Eqs. (1) to (4) define shear stress, whereas Eq. (5) defines critical shear stress. How are they comparable?

A: The parameter used in Eq. 5 is called critical shear stress, but in fact, in this equation as well as hydraulic factors (water depth, water surface slope, specific weight of fluid) as soil parameters (specific weight of sediment, particle diameter) are used. That means he combined soil and hydraulic parameters what is a kind of transport rate (Eq. 20) or detachment capacity (Eq. 26). As called above, in this chapter, we do not want to comment the equations, we just want to present the confusion and the unclear definitions.

Q: P 1252, L 12: "...simplified with time.". Please clarify how the equations are simplified with time.

A: The formulation has been changed to “simplified over time”.

Q: P 1258, L 10: "...in the same dimension.". Please clarify what is meant by dimension here.

A: Has been changed to “the same order of magnitude” following the instructions of the native speaker.

Q: P 1261: Why use only one transport capacity equation when there are many others in the literature, as highlighted by the authors on P 1254? Likewise for detachment capacity.

A: We decided to use the equations used in the WEPP-model (Detachment capacity) or a modified version of the model equation (Transport capacity) as an example for a “typical” physically based soil erosion model. WEPP is well documented so we decided to use this model. It would be very interesting to compare the different transport and detachment capacity equations but this would break the mould of this paper.

Q: Please check that Eq. (27) is correct. Is R in the original formulation?

A: We used the wrong reference. In Foster et al. 1995, the R is not used, Wagenbrenner et al. 2010 used the rill width W. But we replaced the W by the hydraulic radius R because this parameter is more appropriate to describe the hydraulic behaviour in rills. The single rill width disregards the depth, the wetted perimeter can not describe satisfactorily the relationship between width and depth so we used the hydraulic radius.

Q: P 1262, L 15: Why use RME as a measure of variability? RME suggests that the authors are quantifying random errors in measurements. A coefficient of variation would be more appropriate.

A: We used this parameter because we can compare here different units. For example the sediment concentrations show values between 10 and 100 (g L-1), the transport rates between 0.0005 and 0.006 (kg s-1) and the “normal” statistical values like variance or standard deviation are not able to compare different units. Additionally, this values was the best choice for us, because we could directly compare the “correct” value (in this spatial situation, all rills on one field, a model simulation would use an average value for all rills) with the measured values.

Q: P 1264, L 20: The fact that transport rates exceed transport capacities suggests that K_t was underestimated. There appears to be a trend in Fig. 4 towards a constant rate:capacity ratio, which supports the use of Eq. (27) with the appropriate K_t. At low sediment concentrations, the limiting factor may be the rate of sediment detachment rather than the transport capacity. Hence it is not surprising that low sediment concentrations are associated with low rate:capacity ratios.

A: In this figure, there is no kind of steady state. We sorted the sediment concentrations but the temporal trend can not bee seen in this figure. In fact, there are always fluctuations in sediment samples: The first one at one measuring point shows a high SSC caused by a large quantity of loose material, the second and the third show a decreasing trend because the reduction of loose material and the last sample could show a extremely high SSC because of a processes like side wall failure what provides a new material source. The Kt value only regards the grain size distribution, the erodibility of the soil material. Special gravitative processes are not considered. At low sediment concentration ranges the main process is the transport of loose material, this process is caused by flowing water, so the process is (halfway) well described by the used equations and as a consequence, the rate vs. capacity idea is suitable. At high SSC ranges, the main sediment producing processes are more gravitative which are not described by the model assumptions. In fact, it is not surprising that the low sediment concentrations also show low rate vs. capacity relations, the SSC is used to calculate the rates. This figure shows, that under the given experimental conditions, the processes which provide the large sediment quantities are not well described in the models and as a consequence, the idea that the rate can not exceed the capacity without deposition is not suitable.

Q: P 1265, L 4: What is meant by "constant dimension"?

A: Has been changed to “the same order of magnitude” following the instructions of the native speaker.

Q: P 1265, L 4: flow velocity and sediment concentration are input parameters for transport and detachment rates, not capacities. Please clarify.

A: That’s right. “Capacities” was replaced by “Rates”.

Q: P 1265, L 5: Detachment capacity is proportional to excess shear stress, not just shear stress. Depending on the critical shear stress, a small variation in shear stresses may result in large variations in excess shear stress (and hence detachment capacity). The authors’ conclusion here is not justified.

A: Under the given experimental conditions, we assumed the critical shear stress to be constant. In a model simulation, the soil would be regarded as homogeneous, especially in the presented situation. In fact, the given soil is not homogeneous, at one point there are weak points where bank failure can occur more easily as on other positions, but such important variations can not considered by the models. That means in reality, when shear stress increases at a point where critical shear stress decreases, the difference would be high. But when a model assumes that the critical shear stress is constant, a small increase or decrease of shear stress would also just cause a small variation.

Q: P 1266, L 18: Bed shear stress may be partitioned into that acting on bedforms and

that effective in erosion and sediment transport. The authors have not addressed this important issue. How similar are the rills in terms of bedform roughness? If, as is often the case, bedform roughnesses are very different, how would this affect the authors’ conclusions?

A: At the beginning, the rills were very similar, but the rill roughness changed in one rill more than in another, mainly caused by side wall failure. This is also a point which can not be handled in models. The conclusion would not be much different. We observed such processes (involved in the term “side wall failure”) and it is an explanation why the models don’t work: They can not handle these changes.

Q: P 1267, L 5: The fact that rilling involves a number of different processes does not appear relevant here. The different processes do affect sediment supply, but assuming the sediment supply is non-limiting (probably true for where sediment concentrations are high, Fig. 4), sediment transport rates are limited by transport capacities. As Fig. 4 shows, the rate:capacity ratios are roughly constant where sediment supply is nonlimiting. This appears to support the use of shear stress-based equations.

A: In this special study of Govers (1987) it is clearly to see, that the process described by the shear stress is only really important under extreme runoff events. In our experiments, we do not simulate such runoff values. Our experiments are all transport limited. In a supply limited environment, an exceeding can not occur because there is not enough material, in a transport limited environment an exceeding is possible if other than fluvial (e.g. gravitative) processes provide enough material. With our methods, we are not able to show completely supply limited conditions. If there is a mixture of transport and supply limited conditions and the transport capacity is exceeded than is the supply limited condition covered by the transport limited condition. It is possible that there are supply limited conditions if the transport rate is lower than the transport capacity, because it is possible that there is not enough material available for the given processes.

Q: P 1269, L 7: The authors have only investigated the suitability of shear stressbased equations for erosion modeling, and it could be argued (see above comments) from the results that shear stress-based models are reasonably good. The authors' conclusion here appears unjustified. The authors should also investigate the suitability of stream power-based models.

A: In another study, we also tested the relationship between different stream power values and the soil detachment. But the results are similar, there is also no clear (linear) relationship between the hydraulic parameter and the soil detachment parameter. This confirms the results of Knapen et al. 2007, table 1 side 80. Sear stress is used to calculate stream power, depending on stream power variation, flow velocity and water depth is combined with shear stress. The investigation of the stream-power-based models would break the mould of this paper.

Q: P 1269, L 23: Since shear stress is a function of slope, liquid density and hydraulic radius, small variations in these parameters may mean large variations in shear stress. The authors should also take into account critical shear stresses, another source of variability.

A: That is an important point. Of course, there are in most cases differences in the soil shear strength. In this study, we performed our experiments on one field with uniform treatment, so the soil parameters are as constant as possible. And as a consequence, we assumed the critical shear stress to be constant in our experiments. In the WEPP model, the critical shear stress for cropland with a sand content > 30% (at our test side: about 80%, mainly middle, fine and very fine sand) is calculated using the clay and the very fine sand content and these values are constant. The critical shear stress can also change between experiments or within one experiment caused by wetting and drying, sealing and crusting. These changes can not be reflected by the models. We completely agree with the referee and this point is now part of our discussion.

Q: Technical corrections 1. P 1249, L 7: "theses" should be "these". 2. P 1249, L 19:

"oder" should be "or"? 3. P 1249, L 22: "not-everyday" better termed "less common". 4. P 1250, L 7: gamma is "unit weight" rather than "fluid density". 5. P 1253, L 5: change "to find" to "found". 6. P 1258, L 11: change "what" to "which". 7. P 1259, L 9: change "hardly" to "little". 8. P 1260, L 19: change "what" to "which". 9. P 1261, L 17: "A = flow area"?

A: The formulations have been completely revised following the review of a native speaker.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 1247, 2011.