Hydrology and Earth System Sciences Discussions

Interactive comment on "Sediment management modelling in Blue Nile Basin using SWAT model" *by* G. D. Betrie et al.

G. D. Betrie et al.

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We would like to thank the referee #1 for the constructive and valuable comments to the manuscript. We believe readability of the paper significantly improved after incorporating these comments. We replied to all comments individually. Reference is made to the manuscript in case of modifications.

General comment: The authors present a modeling analysis of BMP effectiveness in controlling/reducing sediment yields from the Blue Nile basin. The authors explore the implementation of buffer strip, stone bunding and reforestation on reducing sediment yield from the basin via scenario analysis. They initialize and parameterize the SWAT model for the BNB and calibrate it to measured flow and sediment data at the outlet on

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the Ethiopia-Sudan border. The model yields good results for flow and sediment at the border. While the paper is of interest to readers of the journal, it is currently in need of much work to be acceptable. The manuscript is rife with grammatical errors, and is need of a through editing to improve grammar, sentence structure, and overall flow. I have tried to correct some of the more obvious grammatical and sentence structure errors noted below, but it is by no mean a complete list. Some of the major problems are: 1. There is no discussion of results presented, and thus we as readers are left to speculate what the results can be utilized for and indeed what the significance of the results are. I think inclusion of a discussion would answer some of the questions I have raised below in the specific comments, and would certainly be needed for the work to be acceptable for publication. 2. Perhaps my major concern is with how the various scenarios were parameterized, particularly with how forestation was modeled and with how buffer/filter strips are incorporated into the model. The SWAT model conceptualizes sediment reduction in filter strips as an infinite sink, thus there is no trap efficiency reduction over time, nor any recognition that HRU size should dictate filter width. Trap efficiency decline over time certainly occurs with pollutants such as sediment (e.g.,Verstraeten et al., 2006. Hydrol Proc), and that the sediment loads assumed to be assimilated by the filter strips are unrealistically large in some cases.

Response: The general comments include three main points: (i) Grammatical errors: we agree with the reviewer that the English of the manuscript hinders clear readability. Accordingly, we have critically reviewed and improved the level of the English. Since many changes regarding the editing have been made, we showed the most important changes in yellow highlighter. (ii) Limited discussion of the results: we have included adequate discussion into the revised manuscript, which is shown in yellow highlighter. (iii) Parameterization of scenarios: The forestation is modeled by actually changing the landuse. We agree that the trap efficiency of filter strips decline through time. However, the sediment reduction results are reasonable since they are comparable to results reported by Herweg and Ludi (1999) in the Ethiopian highlands. We have given detailed discussion for this in the specific comment below and in the revised

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manuscript.

Specific comments

Comment: Pg 5501 which version of SWAT was used?

Response: "SWAT2005 version" included in the text, pg 5500 ln 24.

Comment: Ln 7 what process is this referring to?

Response: "continuous-time landscape processes" inserted in the text, pg 5500 Ln 4.

Comment: Ln 24 insert "is between "degradation" and "adjusted"

Response: we have inserted this, pg 5500 ln 20.

Comment: Pg 5502 ln 2-3 might also add that the model input include the tabular data associated with the spatial data

Response: we have included spatial model inputs data in the form of tabular, see Table 1 below and pg 5500 ln 23 in the text.

Comment: Ln 20-21 5000 soil types for the world, not the Blue Nile, might be better to report the number of soils in the basin

Response: We corrected to the Blue Nile, which are 23 soil types; see pg 5501 ln 9.

Comment: Pg 5503 Ln 16 remove "A"

Response: we removed it, pg 5501 ln 30.

Comment: Ln 26 "attest" is not the correct word here, I assume you mean test

Response: attest means to provide evidence

Comment: Pg 5504 Ln 7 I do not think a NSE of 0 indicated acceptable model performance. A NSE of 0 indicates that model performs no better than simply using the observed mean value, you might reconsider how you define acceptable performance.

Later you say NSE>0.5 is satisfactory. This is the definition I would use here as well

Response: We have redefined it, pg 5503 ln 12-13 "simulation judged as satisfactory if NSE > 0.5, RSR $\leq$ 0.70 and PBIAS= $\pm$ 25% for flow and NSE > 0.5, RSR $\leq$ 0.70 and PBIAS= $\pm$ 55% for sediment"

Comment: Pg 5055 Eq 3.Ln 7 "curb" does not seem like the best word choice, perhaps reduce is better

Response: we corrected it, pg 5503 ln 16.

Comment: Ln 16 "built" not "build"

Response: We corrected to "built", pg 5503 ln 24.

Comment: Ln 18 "…and hence, is represented…"

Response: We have included this, pg 5503 ln 25-26.

Comment: Pg 5506 Ln 6-7 a filter strip of 1 m seems rather small

Response: It seems small, but that is actually the size used in the study area according to literature (Hurni, 1985; Herweg and Ludi, 1999;) and first author personal experience. In the Ethiopian highlands, the small-holder farmers are not willing to give more than 1 m strip of land.

Comment: Ln 25 "hamper" is not the best word choice, perhaps reduces, or prevents

Response: we changed this, pg 5504 ln 28.

Comment: Ln 26 "supplanted" would be better as replaced

Response: we correct it, pg 5504 ln 29.

Comment: Ln 27-29 "The evergreen forest was selected because it provides adequate cover against rainfall throughout the year. In addition, the evergreen forest could be easily adapted since it has larger area coverage as compared to other forest type, see

Table 1." I am not sure I understand what these sentences are saying

Response: We have corrected this, pg 5504-05 ln 31-1 "The evergreen forest was selected since it has a wider coverage area than other types of forest in the study area, see Table 2".

Comment: Pg 5507 Ln 2-3 did you not change the actual land uses? It seems that your simulation of forestation was done by simply changing the USLE_C and CN2 values, in which case all the other parameters associated with the previous land uses were left in default? If this is correct, it is somewhat concerning as the evergreen parameters in the model are quite different from cropland, shrubland, and barren, and even mixed forest, and deciduous forest. Did you also adjust the growth and ET parameters to reflect the land cover change? Parameters like the leaf area index and mannings N, and optimum temperature differ quite a lot among these land covers. How were these differences reconciled? And what effect might they have had on the model outcomes?

Response: We modelled the reforestation by actually changing the land uses, not by changing specific parameters such as USLE_C and CN2. When we made the land uses change, all the associated parameters (plant, hydrological and erosion) were changed by the SWAT model from the database. The source of the reviewer confusion may be the sentence at pp 5507, Ln1-3 which should have mentioned the process (i.e., erosion). Thus, the sentence was corrected to" The parameters used to simulate the effect of reforestation on soil erosion…" This explanation has been included in the text; see pg 5505 ln 1-4.

Comment: Ln 6 "transience" is not the right word here. Something that is transience is said to be transient, or brief. I am not sure what is meant here.

Response: we have corrected this, pp 5505 ln 8 "For brevity, three flow and four sediment sensitive parameters are discussed below."

Comment: Ln 9 I don't think you mean to indicate that the CN2 value was -0.02, which

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is impossible. Perhaps you meant to indicate that the base CN2 values were adjusted by -0.02.

Response: We made this sentence clearer, pg 5505 ln 10-11 "The fitted parameter value for CN2 was adjusted multiplying the typical value from the SWAT database by one plus -0.02".

Comment: Ln 11 above you said that CN2, Alpha_bf and rechrg_dp were the most sensitive for sediment "the most three sensitive parameters for flow and sediment…" Here you now say that there are 4 most sensitive for sediment and they are different than above. Of course flow parameters influence sediment parameters, in as much as correctly predicting the timing and magnitude of runoff generation is important in predicting sediment, but the wording of this section makes it confusing as to which parameters are most important for which processes.

Response: We made it clear, pg 5505 ln 6-19 "The three sensitive parameters for flow are…"

Comment: Ln 23-26 these sentences do not work. Does the first refer to the calibration period? As it is now, I cannot tell.

Response: We clarified this sentence, pg 5505 ln 23-24" The simulated daily flow matched the observed for calibration period with NSE, RSR and PBIAS is equal to 0.68, 0.57, and 10%, respectively."

Comment: Pg 5508 ln 3 "it is worth to notice .." should be "It is worth noting that 2001…"

Response: We corrected this, pg 5506 ln 4-5 "The year 2001 is not presented in validation period since the observed data is missing."

Comment: Ln 5-9 Why do you think the model did not capture the rising and receding limbs particularly well? How could the input data be at fault, is it due to precip data being underestimated on the recession and over estimated in the rising limbs, or other

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things such as coarse soils data that might not have accurate estimates of soil properties. Since it seems to be a systematic bias it would seem to indicate an inherent structural flaw with how the model represents the system.

Response: We believe that there is no structural flaw in the model. We included the following explanation, pg 5506 ln 6-13" This could be due to the maximum soil depth ($\leq$ 100 cm) used in this study does not represent soil depth distribution of the basin. In fact, literature shows that the soil depth of the basin is very deep (>150 cm) in the south-west, moderately deep (100-150 cm) in the central, and shallow (30-50 cm) in the north-east and east (FAO, 1986; BCEOM, 1999). Thus, the model did not abstract the right amount of precipitation before surface runoff generation. Subsequently, the simulation was overestimated for the rising limb. This in turns caused less water storage in shallow aquifer and underestimated the base-flow for the receding limb."

Comment: Ln 8 "ascribed" should be changed to "attributed".

Response: we have changed this, pg 5506 ln 16.

Comment: Ln 10-11 "The SWAT sediment simulation part was calibrated from 1990–96 and validated from 1998 to 2003 at El Diem gauging station using daily sediment concentration." Should be changed to "The SWAT sediment predictions were calibrated against measured data from 1990-1996. . ."

Response: we have changed this, pg 5506 ln 21-22.

Comment: Ln 11-12 again 3 "it is worth to notice ..." should be "It is worth noting that the sediment concentration data is available only for rainy season, which occurs from July to October"

Response: we have corrected this, pg 5506 ln 23-24.

Comment: Ln 13 "performance" should be singular.

Response: we have fixed it, pg 5506 ln 24.

Comment: Ln 14-18 "The simulated daily sediment concentration matched the observed for calibration period with NSE, RSR and PBIAS is equal to 0.88, 0.35, and -0.05%, respectively. On the other hand, the daily simulated sediment concentration showed good agreement to the observed with NES, RSR and PBIAS equal to 0.83, 0.61 and -11%, respectively during validation period." Does not read correctly. Change to: "The simulated daily sediment concentrations matched the observed concentrations for the calibration period with a NSE, RSR and PBIAS equal to 0.88, 0.35, and -0.05%, respectively. The daily simulated sediment concentrations for the validation period showed good agreement with the observed concentrations with a NES, RSR and PBIAS equal to 0.83, 0.61 and -11%, respectively."

Response: We have changed this, pg 5506 ln 26-28.

Comment: Ln 13-16 remover this sentence "Thus we found the sediment simulation performance very satisfactory as compared to the performance range provided as a satisfactory (NSE>0.5, RSR_0.70 and PBIAS=$\pm$55%) by Moriasi et al. (2007)." It is not needed as you have already noted what acceptable performance is.

Response: we have removed this, pg 5505 ln 29 - pg5506 ln 1-2.

Comment: Ln 24 change "mimicked" to captured.

Response: We have changed it, pg 5507 ln 9.

Comment: Pg 5509 ln 2 "concentration" should be plural insert "the" between "for" and "whole".

Response: we have corrected this, pg 5507 ln 12.

Comment: Ln 5 "the SWAT model..."

Response: we have included this.

Comment: Ln 14 by "the later" are you referring to bed load?

Response: We have changed this, pg 5508 ln 3 "bed load".

Comment: Ln 15-22 I find it hard to believe that a 1 m buffer along field boundaries would result in 44% reduction (51,000,000 t yr-1). Modeling the effectiveness of buffer or filter strips in SWAT seems somewhat suspect, particularly in a basin as erosion prone as the Blue Nile. Filter trap efficiency in SWAT is modeled as an infinite sink, which might be somewhat believable for dissolved nutrients such as N or P, but it is highly unlikely that a 1 m filter strip maintains trap efficiency particularly in light of the sediment volumes. Thus, large HRUs that produce considerably higher sediment loads surrounded by a 1m buffer strip result in the same sediment reduction as small HRUs that have a considerable smaller sediment load. This results in unrealistically high sediment deposition rates in some of these buffers. Consider for example two square HRUs, one 10 m2 and the other 1 m2. The 10 m2 HRU has a perimeter of 12.64 m and the 1 m2 HRU has a perimeter of 4 m. If both produce the same erosion per m2, say 1 kg m-2 then the 10 m2 HRU produces 10 kg and the 1 m2 HRU produces 1 kg. Thus the 10 m2 HRU filter strip must trap considerably more sediment per unit length (10 kg / 12.64 m = 0.79 kg m-1) than the 1 m2 HRU filter strip (1 kg / 4 m = 0.25 kg m-1). Here I am assuming 100% trap efficiency, but it does not really matter what the trap efficiency is, because it is a constant for any HRU size. I realize that this is simply how SWAT handles the filter, but I think it is critical that you recognize that this is an issue with the model, and the results may or may not (I would argue) be realistic.

Response: We argue that results are realistic since the simulated sediment yield reductions by filter-strips are within range of published results. For instance, Herweg and Ludi (1999) have reported 55%-84% of sediment yield reductions on plot scale in the Ethiopian and Eritrean highlands. However, literature shows that filter-strips become less effective as the scale increase from plot to field due to flow concentration (Dillaha et al., 1989; Verstraeten et al., 2006). For example, Verstraeten et al. (2006) reported low (20%) performance of filter-strips due to overland flow convergence and sediment bypasses of filter-strips through ditches, sewers and culverts. However, we expect less

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overland flow convergence in the Blue Nile since the average farm size is less than $\frac{1}{2}$ ha and the basin is unmanaged (e.g., residential area is <1%). In summary, we must admit that any model is a simplification of the real world and will not be free from limitations. We have added this explanation in the revised manuscript (see pg 5509 ln 13-23).

Comment: Ln 23-24 above you said forestation showed the lowest % reduction (11%), but in Fig 5. It is almost always the highest, certainly above 11%, some well over 70% and none under 11%! IS this a typo in the text or in the figure? Why would forestation affect he sediment yield so much at the subbasin levels and then result in the lowest impact at the basin level. Something does not seem to work out here. This is an example of where discussion might clarify the results being presented.

Response: We have clarified as the following, pg 5509 ln 5-12 "It is important to note that the reforestation effect is higher at the subbasin level than at the basin level. The reason is that the reforestation implementation area was proportional to filter strips and stone bunds at the subbasin level. For instance, in the subbasin-1, agricultural land covers 1.7% and reforestation covers 1% of the total area. In the basin level, however, the reforestation covers 8% and agricultural land cover 17% of the basin area. Thus, the effect of reforestation in the basin level was masked by the higher sediment yield from agricultural land. These results corroborate Santhi et al. (2005) findings that showed reductions in sediment and nutrient up to 99% at farm level and 1-2% at the watershed level."

Comment: Pg 5510 Ln3 insert "the" before "upper".

Response: We have inserted this, pg 5510 ln 5.

Comment: Ln 6 remove "A" and capitalize daily.

Response: We have corrected this.

Comment: Ln 10 remove "On the other hand" this implies that you are presenting

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results that counter the previous sentence, which you are not.

Response: we have removed it.

Comment: Ln 13 remove "computed to be" and replace with "was".

Response: We have removed this, pg 5510 ln 8.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/7/C2883/2010/hessd-7-C2883-2010-supplement.pdf

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