Hydrol. Earth Syst. Sci. Discuss., 8, C1775–C1785, 2011
www.hydrol-earth-syst-sci-discuss.net/8/C1775/2011/

Hydrology and Earth System Sciences Discussions

Interactive comment on "An efficient semi-distributed hillslope sediment model: the Anjeni in the sub humid Ethiopian Highlands" *by* S. A. Tilahun et al.

S. A. Tilahun et al.

tss1@cornell.edu

Received and published: 26 May 2011

We are very appreciative of the comments of reviewer 1. Thank you so much for your time! We have implemented most of the changes suggested. In the few cases that we did not agree we explained the reason. Below we have quoted the comments of the reviewer followed by our response. In addition we noted in red in the manuscript text the additions made. For clarity we did not mark the original text that was removed.

Comment:

First of all it is not made clear why daily sediment concentrations were calculated although one has a more detailed data set available. I presume this was done because also the discharge model is run on a daily basis but this is not stated explicitly.

Response:

The reviewer is correct that we did not state clearly that we simulated daily sediment concentrations. To state distinctly that we ran the program at a daily time step, the following sentences are included in the methodology and results section;

In section 2.1 beginning: Âň"The model predicts daily and sediment concentrations. A daily time step was chosen for predicting discharge because rainfall distribution during the day was generally not available. The prediction of the daily sediment concentration is based on the concept that erosion is produced in areas with surface runoff. Thus, in our hydrology model that simulates surface runoff from saturated areas and degraded hillside areas, erosion is only simulated from these runoff producing source areas."

At the end of section 2.4: Event based sediment yields were summed over a daily period to determine daily sediment load. Daily sediment concentration was determined by dividing the daily sediment load by the total discharge during that day. These were then compared to the daily predicted sediment concentrations.

In section 4 in the beginning: "A comparison of predicted and observed daily stream flow for the watershed is shown in Figs 4 and 5 and that for sediment concentrations in Figs.6 and 7"

Comment:

The model implicitly uses a transport capacity limited approach to model sediment transport. Are there any (field-based) arguments for this? Is it not possible that some (steeper) slope segments in the degraded area could potentially transport more sediment than what is made available by erosion processes on more gently sloping land further up-slope?

Response:

The hydrology model simulates reasonably the rainfall and runoff process in the watershed. It is clearly shown in the paper that major portion of the watershed is an infiltration zones where there is no runoff to transport sediment. In the other regions where runoff is produced, there is transport of sediments. In the watershed, there are areas covered by soils of shallow and low conductivity where sediment is transported through small traditional drainage ditches and empty out in larger drainage ditches where the soils can pick up more soil by eroding these larger drainage ditches. So indeed we are modeling a transport limited approach. This is included in the section 2.2.2 in the beginning as follows:

"The model sediment we assume for simplicity that the sediment transport is transport limiting. Then for the two source areas, the mean suspended sediment concentration C (g/L) is a function of flow rate and a coefficient dependent on landscape and sediment characteristics. . .. . ."

In addition we added to a few sentences in section 4.2 about the location of the degraded areas are occurring:

"In Anjeni, these areas are located in the watershed on the fields in which the farmers have the traditional small drainage (or cultural) ditches on the shallow and slowly permeable soils. (Leggesse, 2009)"

Moreover, the presence of gully in the watershed act as sediment source through head cutting process by covering eroding surface of the watershed as described in Ciesiolka et al., 1995. To include this, we add the following statement in 4.2 section as follows

"The assumption of transport limiting for sediment transport seems working in this watershed. This is likely due to the presence of gully in the watershed as active head cutting provides enough sediment sources to be modeled as transport limiting (Ciesiolka et al., 1995). In addition, the incorporation. . ..."

Comment:

The three regions are now treated more or less as a black box: average values for the coefficient "a" are calibrated irrespective of the variability in slope, slope length, rougness, .. within each region. This implies that the calibrated parameters will only be valid for this watershed under current land use conditions. It will not be possible to use this calibrated model for other watersheds as these will have a different setting (slope distribution, soil typology, : : :). Hence, what is the value of this model approach when it cannot be extrapolated? The model can also not be treated as a semi-distributed model such as the title suggests given the fact that the three regions are black boxes.

Response:

The developed model is semi-distributed in that it divides the watershed up in different regions that become runoff source areas and recharge areas given different amounts of effective cumulative rainfall after start of the rainy season. A separate water balance is run for each of the hydrologic regions using rainfall and potential evaporation as the major inputs. Those regions that produce runoff are considered as source of sediment and these sources are considered applying two different parameters for the two runoff source areas in the simulation of sediment. Moreover the statement that these regions are black boxes is not completely valid. We simulated the subsurface and interflow in these regions and used them in calculating the sediment concentration. The reviewer is correct that we calibrated the parameters, but that is the case for almost all models including SWAT.

Comment:

The hydrological model is also overparameterized: with nine calibration parameters it is not so difficult to get a good model fit. But this does not mean that the current combination of the nine calibration values is meaningful. Other combinations could also give good predictions. However, this kind of information is not provided. What is the range of model efficiency values for a range of parameter values?

Response:

HESSD

8, C1775–C1785, 2011

The sensitivity analysis shows that the area proportion of hillside (A3) is a highly sensitive parameter while the maximum baseflow storage (BSmax) is insensitive. In addition, the model is not very sensitive to the storages Smax of each of the tree zones. The model efficiency calculated for a change of 30% of the average value is in the range of 0.63 to 0.81. For most of the parameters, the changes produce efficiency close to 0.80 while a 30% change of area fraction produces a lower efficiency of 0.63. Increasing either the saturated area by 15% of the watershed or the degraded area by 50% of the watershed area (and not by 30% of the average value) resulted in a decrease of the efficiency to 0.46 and 0.07, respectively. Thus the model is highly sensitive to the relative areas and less sensitive to any of the storage values as they affect the outflow only in the beginning of the rainy season. The following was added to the text:

"A sensitivity analysis of the hydrology model over the validation period is presented in the auxiliary material. The model was fitted visually and not according to any particular statistics. The most sensitive parameter is the fractional areas that produce runoff and recharge. Increasing the recharge area by 30% (or 15 % of the total area), the NS efficiency decreases from 0.8 to 0.63. For a similar decrease of 30% the NSE efficiency became the same, i.e., 0.8. An increase of saturated runoff area by 15% of the total areas, the NS efficiency was 0.46 and for a 50% increase of the degraded area from the total area, it became 0.07. The reason for the sensitivity is that the overall balance is not met. Moreover changing recharge areas to runoff areas resulted in the peak of the runoff be earlier (Tesemma et al., 2010). As expected the N-S efficiency is insensitive to variation in amount of water that can be stored in the root zone. The reason is that the magnitude of the storage affects only the first runoff events after the rains has started. Since it rains often during the rainy season, these soil remains near full capacity and total size of the storage affect only minimally the amount of recharge or runoff. This will not be the case for temperate climates where the large storms are more infrequent. Finally the model is not greatly dependent on the subsurface flow parameters. Testing has shown that when changing the parameters by a factor of two the baseflow tail is affected. Since the deviations are small the N-S efficiency stays the same but the relative mean square error and the visual appearance is affected.

Consequently the hydrology model was only sensitive to fractional areas and one can assume that the fitted values are reasonable close to the optimum values. For the other model parameters a wide range of values exists that give the same N-S efficiencies. This implicitly means that the model structure is correct, because the physics indicate that the sensitivity should be small. It also indicates that using an average for the spatial variation of these parameters does not affect the model output. This could be the reason for the high efficiencies compared to other models tried for Anjeni (Easton et al., 2010 and Zeleke, 2000)."

With respect to the over parameterization: It is true that one can predict most hydrographs with five parameters in temperate climates. In our case by combining the degraded area with the saturated area we are at 7 parameters and the predicted results remain good. In addition we can have only one type of groundwater subsurface flow (making it 5 parameters) but the recession flows are significantly less good simulated, although it is marginally reflected in the efficiency values This is obvious because hydrographs of monsoon climates have two distinct slopes in the recession curves during the month without rain (that can be roughly separated in fast (interflow) and slow (baseflow). Thus it seems that for monsoon climates we need a maximum of seven parameters to obtain a reasonable fit. In our approach in the hydrology model we wanted to keep some resemblance to the real landscape and that is why we added two runoff areas that are also distinctly different in their location in the landscape.

Compared to other models such as SWAT that predict sediment concentrations our model with only nine (plus 2 for sediment) parameter does not have a lot of parameters.

Comment:

The model assumes that the nine calibration parameters, and thus also the fraction of the three regions, are constant for the watershed through time. But is this realistic? What about the variable source area concept? Is this not valid for this catchment?

HESSD

8, C1775–C1785, 2011

Does the area with saturation excess overland flow not vary through time, over the years, during the rainy season, etc, and thus also the area with erosion?

Response:

Yes, this is true that the parameters and area ratios vary with time. The model, for example, under predicted peak runoff periods during wet seasons (peak flow) likely because of an expansion of runoff producing areas, in which this model fixed those areas. We can describe this increased runoff by introducing more parameters, but more experimental watershed data is needed to describe this well. The model would then even more than the nine parameters (see earlier comment). Despite that our Nash Sutcliffe values for daily predictions are as good or better than monthly values of other models that are used for this watershed and published that did not include the concept of saturation excess runoff. In summary our model can use improvements, but currently does well or better than other models using more variables

Comment:

How sensitive is the model when the calibration parameters change? How sensitive is the model for changes (or errors) in input values?

Response:

We performed a sensitivity analysis and the results are given in the auxiliary material. A detailed answer is given above.

Comment:

Plots like figure 4 and 5 always give a false impression of the goodness of the model predictions. Off course, the predicted runoff will increase when the observed runoff increases: this is quite logic as there will only be runoff after rainfall. Likewise, if there is no runoff, there will be no sediment transport/concentration. It would therefore be better to plot the observed versus the predicted values of daily Q and C in one graph to see how far the predictions plot from the 1:1 line.

HESSD

8, C1775–C1785, 2011

Response:

As per suggestion, plots of observed versus predicted values of daily Q and C are included in the document. This is done for both calibration and validation steps (Figures 4 and 6). The figures are attached as figure 1 and 2.

Comment:

The quality of Figure 1 is insufficient, especially the DEM (only three odd-chosen colors).

Response:

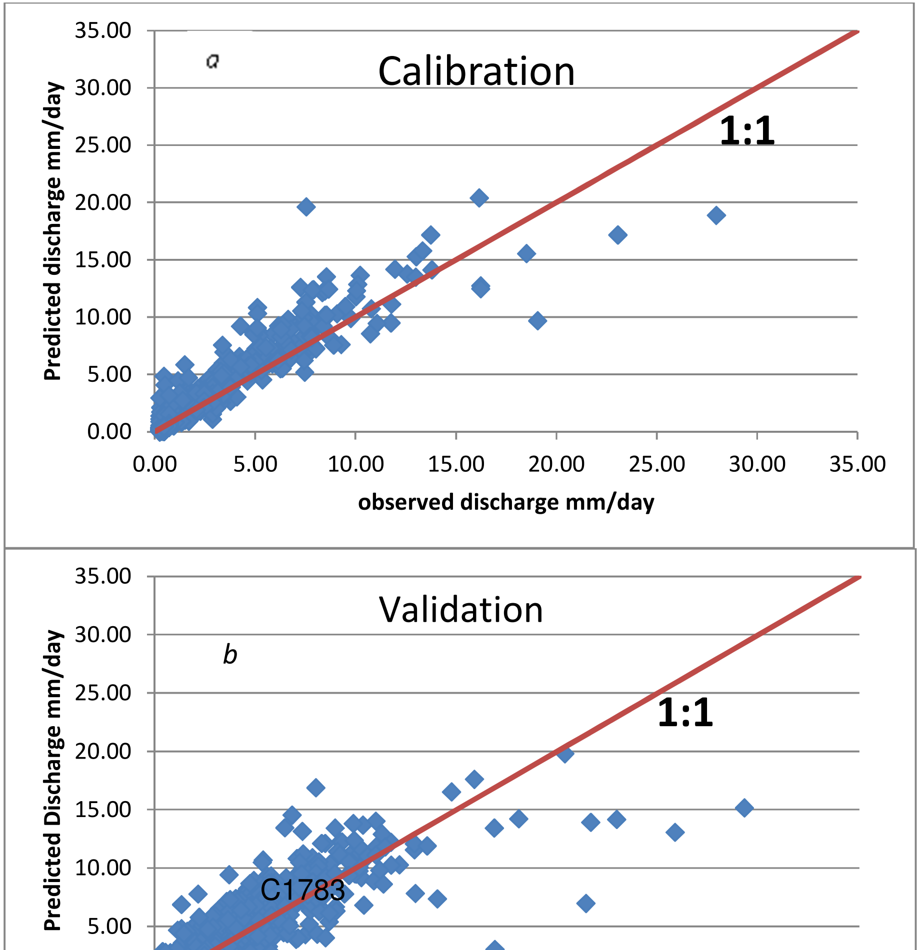
Figure 1 is improved and can be referred and is replicated as Figure 3

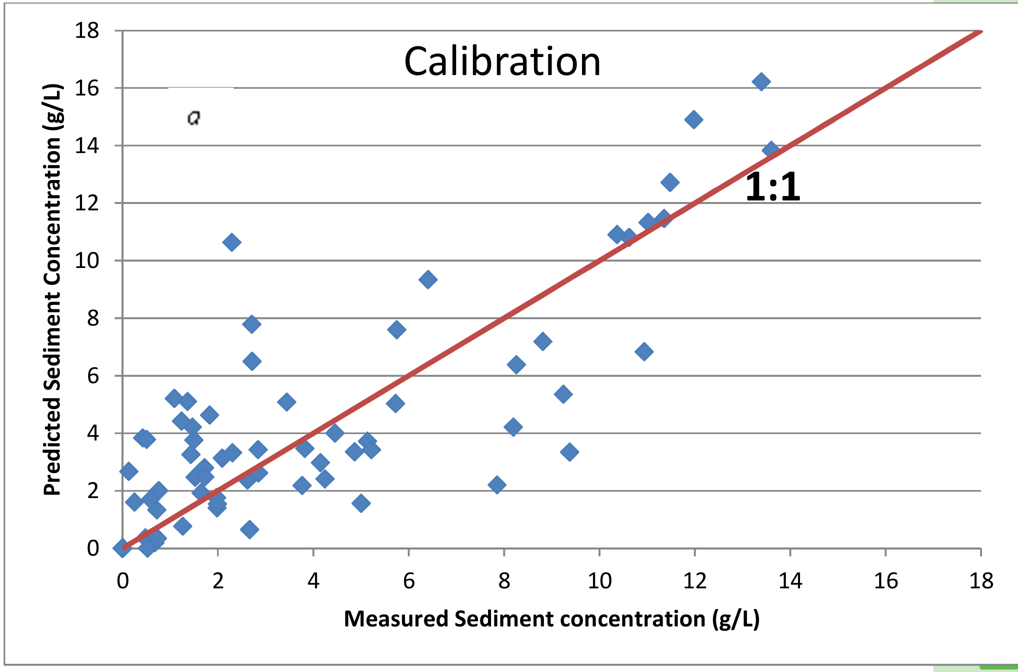
Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 8, 2207, 2011.

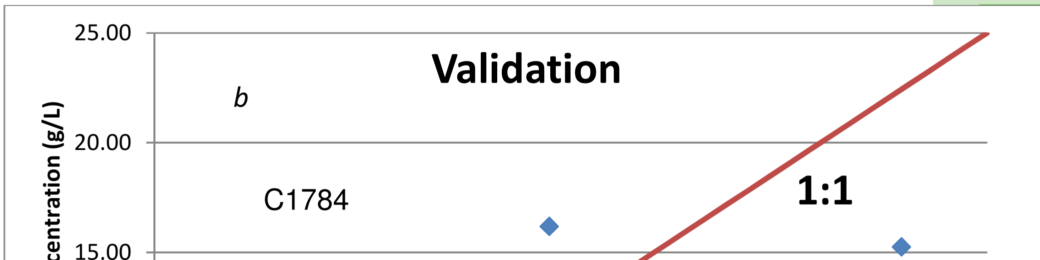
HESSD

8, C1775–C1785, 2011

Interactive Comment







Full Screen / Esc
Printer-friendly Version
eractive Discussion
Discussion Paper

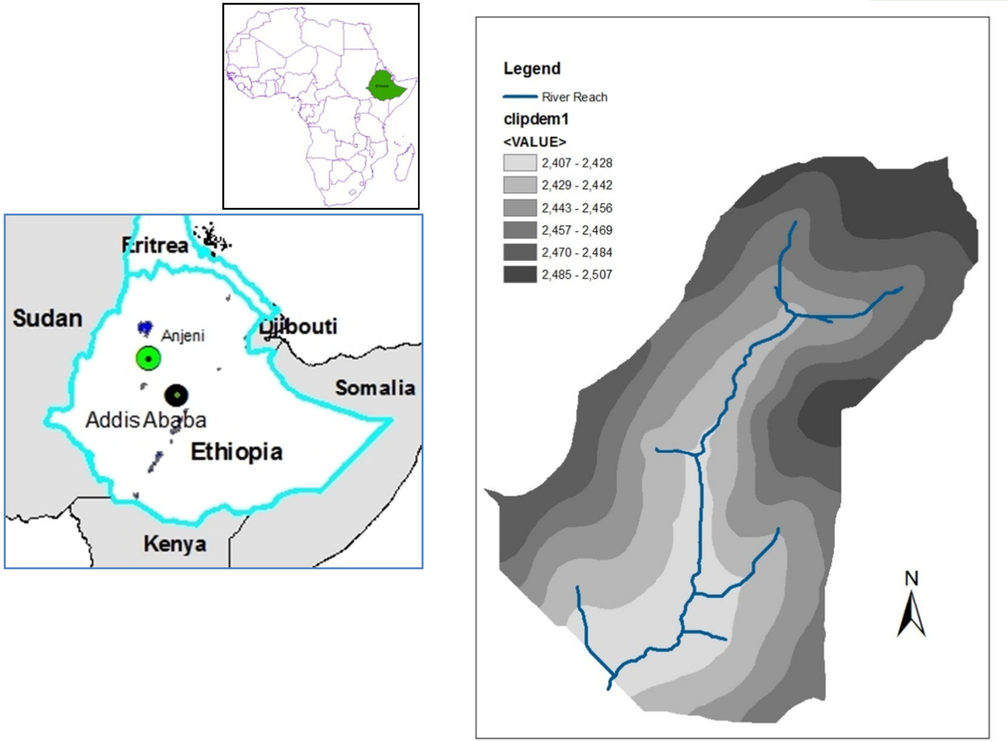


Figure 1: Location, watershed boundary and drainage map of Anjeni Watershed