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Hydrology and Earth System Sciences Discussions

Interactive comment on "Prediction of runoff and discharge in the Simiyu River (tributary of Lake Victoria, Tanzania) using the WetSpa model" *by* J. Rwetabula et al.

J. Rwetabula et al.

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Response to comments of the reviewers

Comments by S. White (Editor)

This paper deals with an application of an exiting hydrological model, WetSpa, to a catchment draining to Lake Victoria in Tanzania. The catchment is of importance because of high pollutant loads from agricultural sources delivered to the lake. This paper uses WetSpa to investigate water balance characteristics of the catchment as a precursor to water quality modelling.

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Interactive Discussion

Discussion Paper

General comments

The Simiyu basin, as for many in Africa, has sparse data. This applies to both spatial information on land use and soil and temporal data relating to precipitation, evaporation and river flow. Given such data consideration of whether WetSpa is an appropriate modelling technique would be helpful.

Answer: Most model parameters, including all spatially distributed basin properties, are automatically derived from the basic input data using a data base included in the WetSpa model. All parameters provided in this data base are physically based and not site specific, which makes the model ideally suited for applications where comprehensive field data is lacking, as is often the case in underdeveloped countries. We have added this comment in lines 201-206 in the revised paper.

The paper is really about estimating river discharge and the title should reflect this.

Answer: The title of the paper has been changed to: Prediction of daily discharge in the Simiyu river (tributary of Lake Victoria, Tanzania) using the WetSpa model.

In the section on model input more detail is needed about how soil parameters are derived from the soil map, and indeed what parameters were available for each soil type.

Answer: There were no specific soil data available except for the soil texture map. For the derivation of soil parameters the standard WetSpa data base was used. We have added a new figure (Fig. 1) which explains this procedure; see lines 201-203.

In the section on model calibration please add a table showing ranges of parameter values and final calibrated values.

Answer: A new table (Table 1) has been added to show ranges of parameter values and final calibrated values. Additional comments about this table are given in lines 325-337 and lines 355-365.

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For those data from lookup tables which are not calibrated please state their relevance to African conditions.

Answer: All parameters provided in the data base of WetSpa are physically based and not site specific. This is explained in lines 201-206 in the paper. The model has also been successfully applied in other tropical countries as Vietnam and Surinam. This is also stated in the paper in line 75.

I am concerned that the calibration and verification periods used for the model overlap substantially. Data exist for the period 1999-2004 and yet calibration has been carried out from 2001-2004 and then verification from 1999-2004. This is not normal practice and the two periods should not overlap. I suggest splitting the time period in two and carrying out an independent calibration and validation exercise.

Answer: There is some confusion here due to the imprecise description in the original text. For this study, data was collected by the authors only from 2001 onwards. Older data was obtained from government institutions, but this data is very unreliable, in particular the river stage data. Therefore, the model was calibrated using only the 2001-2004 data. Afterwards the model was not verified, but it was applied for the 1999-2004 period (hence, using precipitation data covering 1999-2004), in order to obtain information on the mass balance and hydrological processes over a full 5 year period. We have corrected this in lines 370-374. The suggestion to split the data in a calibration and verification period is very difficult to do, because the data set is rather short and imprecise. The model already performs not so good when calibrated for the whole period; hence, it will be much worse if we split the data series. Anyway, the goal is not to predict daily stream flow accurately, but to obtain general information on the mass balance and overall hydrological behavior of the basin.

There is confusion about groundwater in the paper. Table 1 says there is no groundwater input to the river and yet there is quite a high percentage of percolation. In the paper there is discussion about a groundwater threshold level which has not been reached,

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but perhaps this percolation is just a factor which allows the model to be calibrated reasonably well? This is often the case in other distributed hydrological models.

Answer: There is again a lot of confusion here because the text was imprecise which makes the water balance presented in the previous Table 1 (now Table 2) difficult to interpret. We have improved the discussion on the mass balance by including a visual representation of the different mass balance components in a new figure (Fig. 10). In this figure the different components of the evapotranspiration are shown separately which improves the interpretation of the mass balance considerably. Now it becomes clear that the recharge is added to the groundwater storage but is mainly lost by evapotranspiration. The discussion in the text has been improved in lines 447-474.

I am concerned about some of the model evaluation criteria, especially as Figure 8 seems to show rather more bias in results. The overall efficiency of 57.4 percent is not good compared with other applications of WetSpa and we have no detail on the formulation of the final two evaluation criteria which focus on low flows and high flows

respectively. Why are these used when Nash-Sutcliffe already gives more weight to evaluation of high flows?

Answer: The original Fig. 8 (now Fig. 9) was confusing because it also contained the period Jan-May 1999 for which the stream flow data are very inaccurate and unrealistic. Because these data are not used for calibration or for evaluation of the mass balance, we removed this part of the figure and also expanded the x-axis of the figure, such that the figure (now Fig. 9) is easier to interpret. The evaluation criteria for low flows and high flows are standard evaluated in the WetSpa model. Their meaning is explained in the manual and the references cited in the text, and we think we need not go into more detail in this paper. However, we have included the formulae for the different evaluation criteria in the text in lines 386-392 for clarification.

Table 1 is extremely confusing and needs clarification. In particular the column headed percentage - this is percentage of what? I could not reconstruct a water balance easily

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from this table which is surely what it is supposed to facilitate. Footnote (a) should I think read excluding missing data. The numbers in the table do not seem to agree with those in the text: for example in the table percolation is given as 38.8 percent whilst in the text is given as 42.2 percent - in either case this is a lot of water to be lost to some hypothetical groundwater store which does not reappear.

Answer: We have stated in the corrected text that the percentages relate to the precipitation (line 448). In order to improve the understanding of the table, we have added a visual representation of the different mass balance components in a new figure (Fig. 10). This figure also clearly shows the different components of the groundwater storage. The errors in the text have been corrected so that the numbers agree with the table. More explanation is given about the different terms of the water balance especially about the groundwater terms (lines 463-484).

In view of the comments about calibration, validation and evaluation, the model performance needs more careful assessment and the discussion and conclusions should reflect this.

Answer: The discussion and conclusions have been adapted accordingly.

Figure 8 is difficult to read and interpret because the rainfall and flow bars overlap - please expand one of the scales so that bars do not overlap.

Answer: This figure (now Fig. 9) has been improved so that it is much easier to interpret.

Please add scales and N arrows to all maps.

Answer: all maps have N arrows and scales.

Required grammatical corrections

Introduction

Paragraph 1, line 5 .is mainly from fertilizers and pesticides

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Paragraph 3 line 1 The main contributions to the pollution load of Lake Victoria from Tanzania are from the Mara, Kagera and Simiyu basins.

Paragraph 3 line 4 .generating high yields of sediment

Paragraph 3 line 7 indicating that the majority of contaminant is

Paragraph 3 line 10 Hence, proper water quality

WetSpa model (theory)

Paragraph 1 line 8. running the model and parameter selection is..

Paragraph 3 line 1 .depends on storm intensity and vegetation.

Paragraph 3 line 9.is regulated by the evaporative demand.

Paragraph 4 line 9 .Thornthwaite and Mather

Paragraph 4 line 12.evapotranspiration as a function of.

Paragraph 5 line 2.higher than field capacity, as a function of.

Paragraph 6 line 1 .routed

Paragraph 6 (between equations 6 and 7) by integration along the topographically determined

Paragraph 7 line 1 .interflow along its topographically.

The Simiyu catchment and field data collection

Paragraph 1 line 1.in the southeast of Lake Victoria, Tanzania

Paragraph 1 line 5 maps at scale 1:50,000

Paragraph 1 line 8 training sites for a supervised classification

Paragraph 1 line 9 Figures 2, 3 and 4

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Interactive Comment

Paragraph 2 line 2. Five and a half years

Paragraph 2 line 7 ..and 20 percent during other months.

Model input parameters

Paragraph 1 line 2..hydrological features such as surface slope

Paragraph 1 line 4 is considered to be drained.

Paragraph 2 line 8 ..for a relatively flat area

Model calibration

Paragraph 2 line 5 simulation period is very low, which is likely to be due.

Paragraph 2 line 7 .rather large, which can be related

Paragraph 2 line 13 .with a relatively high permeability.

Model results and discussion

Paragraph 1 line 1..is verified for a longer period.

Paragraph 2 line 6 ..that do not capture

Paragraph 2 line 8 short term flash flows.

Paragraph 3 line 1 The required number of precipitation .....gauge density) for good evaluation of precipitation input is discussed

Paragraph 3 line 4. for a large catchment such as the Simiyu river

Paragraph 3 line 6 water level recordings

Paragraph 3 line 7 A final source of error

Paragraph 7 line 2.and 0 percent of the total discharge.

Paragraph 8 line 9 .contributes about 9 percent...

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Conclusion and recommendations

Paragraph 1 line 1 .A spatially distributed hydrological simulation.

Paragraph 2 line 7 .cannot capture flash flows

Paragraph 3 line 1 is about 2.4d with a maximum of 8d

Paragraph 4 line 1 is 61.4 percent of the total discharge

Paragraph 4 line 2 interflow may be caused by

Paragraph 5 line 3-4 .which are transported to and deposited in Lake Victoria.

Answer: All these errors have been corrected.

Comments by anonymous Referee #3

General comments:

The paper describes the application of the WetSpa Model to the Simiyu river basin, a tributary of Lake Victoria (Tanzania). This river is of major concern due to important water quality problems that eventually also threatens Lake Victoria. Since the discharge of the Simiyu river was not monitored until recently, the authors have tried to apply the WetSpa model to this river basin, so to obtain discharge information that would in the end also help in estimating the pollutant loads going into Lake Victoria. The paper does not introduce any new concepts in the field of hydrological modelling. It is a case study where a well-known model is applied to a new region of climatological and physiographical conditions.

Answer: We agree with the reviewer that this paper does not introduce new concepts, but is just a case study performed in an area where previously not much was known about the hydrological processes. Because this catchment drains to Lake Victoria, the obtained results can be of interest for other researchers in this region.

Specific comments:

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The title should be shortened by only referring to discharge: Prediction of daily discharge in the Simiyu river (tributary of Lake Victoria, Tanzania) using the WetSpa model.

Answer: The title of the paper has been changed as suggested by the reviewer.

In section 2.2 the authors refer to the estimation of evapotranspiration by the means of pan evaporation data. Some additional information on how this was done would be welcome.

Answer: A short explanation on the conversion of the pan evaporation data has been added in lines 240-242.

The relationships that were used in section 3.1 to determine the potential runoff coefficients via slope, soil type and landuse should be explained with more details.

Answer: We have added a new figure (Fig. 1) to show how spatial data are as the potential runoff coefficients are estimated from the digital maps of slope, landuse and soil type, by an automatic standard procedure provided in the WetSpa model (lines 263-265). We also refer the interested reader to the WetSpa manual (lines 282-284).

In the model calibration (section 3.2.) description the authors refer to PEST. They should indicate that this refers to: Parameter EStimation Tool. It would be necessary to indicate for each parameter to what corresponds the - reasonable range - within which the authors vary the model's parameters during the automated calibration procedure.

Answer: We have indicated that PEST refers to Parameter EStimation Tool (line 312). A new table (Table 1) was added with an overview of the global parameters that are calibrated, their feasible range, and resulting PEST estimates. The discussion of the calibration results has been extended (lines 325-365).

The sentence on - spatial parameters and parameters in the lookup tables - at the end of the first paragraph of section 3.2. does not look very clear. What is the exact

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difference between the two?

Answer: Spatial parameters are not calibrated, but are automatically derived using the WetSpa data base; this has been clarified in the text (lines 263-264, and 306-311).

Given the lack of climatological and hydrological data of sufficient spatio-temporal resolution, the application of the model has proven to be quite problematic. This aspect of the study set aside, the overall approach for the assessment of the performance of the model that has been chosen needs some additional clarification. The authors refer to a calibration period of the model which reveals to be very similar to the verification period. This is problematic, in the sense that the calibration period of the model should not overlap with the validation period of the model, so to guarantee for a proper assessment of the model's performance. Why did the authors not split the observed data set in two periods of equal length and used them for calibration and validation of the model? By switching the data sets the same operation could have been performed again, so to account for the relatively short period of discharge observations.

Answer: In the original paper this was not well explained. There was no model verification; the so called verification was the calculation of the mass balance over a larger period than the calibration period in order to have a period of 5 complete years. This has been corrected in the revised paper (line 374). We think that splitting the date set in a calibration and a validation period will be very difficult, because the time series are rather short and the overall quality of the data is not so good. With all reliable data combined for the calibration we only obtain an efficiency of less than 60%; hence, if we split the data this could improve somewhat for the calibration period but will certainly be much less for the validation period. As stated in the conclusions, we do not think that the model can accurately predict daily flows, but the overall water balance is probably more reliable, which we consider as the goal and main result of this study.

In their comment of figure 8 (section 3.3.), the authors state that - concentration time and flow volumes are accurately predicted -. They also refer to the maximum recorded

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peak rainfall intensity of 48 mm/d and a corresponding maximum observed peak discharge of 208 m3/s: from figure 8 it rather seems that the rainfall occurred around February 1999, while this maximum discharge happened around April or May 2002. Maybe this is only due to the high density of information in figure 8, which renders it rather difficult to interpret. In any case, in their comments the authors should be more careful in evaluating the model's performance. It is rather surprising that the model bias is of only 2.4%, while the model efficiency is of 57.4%, which indicates a rather low performance. Some further developments on this would be needed. Figure 8 rather suggests that the modelled discharge is most of the time largely over-estimated compared to the observed discharge. Furthermore, in figure 8 the observed discharge during early summer 1999 indicates a kind of slow recession that might be due to some groundwater contribution. It would be good to comment on this observed feature, which was by the way not simulated by the model. A final remark concerning figure 8 concerns the rainfall : it looks as if there were several grey-scales for the rainfall bars ? Would it not be good to zoom into a given part of the whole period so to have more details being visible, which would then help for the interpretation?

Answer: We have corrected the text as - concentration time and flow volumes are reasonably predicted (lines 406-407). The original discussion on maximum rainfall and peak flow was confusing; it did not refer to the same event. Hence, this has been corrected in lines 407-408. The previous figure 8 (now Fig. 9) has been improved so that it becomes much better to interpret. The conclusion that most observations are underestimated is misleading because the peak flows stand out more clearly, but there are large periods were very small or zero flows were observed, and where the model predicts some discharge. Anyway, the comments have been adapted in lines 408-419. All data of early 1999 have been removed from the figure, because these observations (not made by us) are unrealistic and probably unreliable. The representation of the rainfall has been improved and the figure was elongated along the x-axis so that more details become visible and a better interpretation is possible.

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The comments in the second paragraph of section 3.3 should be skipped, since they are both too optimistic and put before the actual assessment of the model's performance via the evaluation criteria (4th paragraph of section 3.3.).

Answer: This part has been adapted. The evaluation criteria are first explained and discussed (lines 378-379), followed by a more critical discussion of the comparison of observations and simulations (lines 406-419).

With respect to the above comments the authors should rewrite the conclusions of their paper and evaluate the performances of the model more carefully.

Answer: The conclusions have been adapted.

All references cited in the text are listed in the references list.

As previously stated, this paper describes a model application to a river basin with little available hydro-climatological information. The description of the model calibration and validation procedure, as well as the evaluation of the model's performance needs to be largely improved. Therefore, this paper should be subject to a moderate to major revision.

Answer: The description of the model calibration and evaluation of the model performance have been improved as suggested by the reviewers.

Technical comments:

1 Introduction - 1st §, line 5 : — is mainly due to fertilizers — - 2nd §, line 3: The hydrological cycle — - 3rd §, last sentence: Therefore, models capable of predicting discharge and water quality are needed to predict the effects of land use and waste management for decision making. - 4th §, last sentence: — will be useful to estimate chemical loads —

2.2 The Simiyu catchment and field data collection - 1st §, line 6: (Meertens and Lupeja, 1996; FAO, 2002) - 2nd §, line 2: Five and a half years —

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3.3 Model results and discussions - 3rd §, line 1: The required density of precipitation gauging stations — - 3rd §, line 6: — estimated from the daily water level recordings cannot capture all discharge variations.

Answer: All these errors have been corrected.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 4, 881, 2007.