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Hydrology and Earth System Sciences Discussions

Interactive comment on "A modeling approach to determine the impacts of land use and climate change scenarios on the water flux of the upper Mara River" *by* L. M. Mango et al.

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Dear Editor and reviewers:

We thank you for the valuable comments and reviews provided. We have found the comments useful and will help strengthen the manuscript. The reorganization and some technical comments raised are all addressed. We have shown the response below each comment. We have added new tables and figures were added and also redrawn. New simulations on climate change scenarios and the corresponding results were added.

Authors

Anonymous Referee #1

General comment: The paper describes a study on the effects of land use and climate change on the water resources of the Mara. Such types of studies are very useful for sub-Saharan regions that are subject to global changes potentially effecting their hydrology and are therefore relevant for a HESS journal.

Response: Thank you

The paper is fairly written but needs some clarifications at several places. More importantly, the conclusions are driven to easily, as I see a couple of limitations in the study. I do not see how state of-the-art research is used for this study (literature review is lacking) or any novelty in the methodology.

Response: We have now rewritten the conclusion based on the changes we made to some parts. It now reflects the content of the revised section. We have also added new literature reviews on hydrology and climate change in the front part of the manuscript. We have also shown the contribution of such study in area like Mara River were the effect of simultaneously happening land use and land cover changes will change the hydrology of the basin on which many sectors depend for its water resource. The manuscript also used a satellite-based rainfall, RFE as an input to the model after generating artificial rain gages to represent rainfall reading points by converting the gridded rainfall to time series point data.

In addition, the used methodology is not well validated (poor model validation, no attention to spatial representation of processes and/or parameters in the hydrological model).

Response: The model was recalibrated using a different algorithm ParaSol and SUFI-2 and this has resulted in better calibration and validation values (NSE 0.43) which is considered fair

Main comments: (1) The paper lacks a proper literature review on model application in the Mara and the use of hydrological models to study land use and climate change (many exist). Response: A proper literature review has been added to address this (Hydrological model types allowing/facilitating scenario development, Hydrological - runoff modeling in regions with scarce data, Advantages of the Soil and Water Assessment Tool (SWAT) Model, Scenario building, Land Use change Scenarios and Climate Change Scenarios). Not many hydrological and land use change models have been applied in the Mara basin but those that are known to have been applied have been mentioned.

(2) The hydrological model SWAT is proposed to compute the effects on the hydrological cycle. While SWAT is indeed described as a model that can be used for ungauged basins, one should be careful with this statement in applications outside of the US. The most important hydrological parameter, the Curve Number, has been assessed for soil and land uses in the US based on large datasets. However, for Africa these default curve numbers do not exist. An appropriate calibration is an alternative but at the same time it remains difficult to identify the distributed parameters that should represent the spatial variability in the land use.

Response: These curve numbers were computed based on the other soil parameters and these were used to represent these distributed parameters. The good part of SWAT model is its applicability in different agro climatic zone. Yes the model is developed for US soil and land use condition. But the model is developed in a way that each parameter were set with allowable range and the calibration process will limit the testing of different parameter set within the range so that different area and hydrological setup will have specific set of hydrological parameters. The model can be used in ungauged watershed by upscaling the calibrated parameter to a relatively similar watershed.

(3) The methodology for land use change analysis can be questioned. A distributed hydrological model is used that should allow for land use change assessments. Nev-

ertheless, the model has been calibrated by using a single dataset at the outlet of the sub-basin. On top, the results, especially for the validation period are poor. It can be questioned whether the individual land uses are properly identified. I would rather speak of a land use sensitivity study. More important, the study does not report on more important changes in land use: moving from rain-fed agriculture towards irrigated agriculture. Effects are mainly expected of those changes, especially when associated with dam constructions. It is also not clear how the land use changes were implemented. Were new land use maps created or were the changes done directly in the model (changing the fractions)?

Response: A better calibration was carried out using a different algorithm and resulted in better calibration and validation results. Identification of land uses was done by actual visits to the field and these field trips also served as ground truth for the remote sensor data that was used for the land use classification in addition to existing land cover maps like the 2002 Africover land cover data by FAO. The land use change scenarios explored in this study are based on historical and emerging land use and resource use trends. These were decided upon after observation of old maps and data and discussions and consultations held with area residents, environmental experts and water resource managers.

(4) For climate change, the authors use the so-called 'delta-t' method to compute future climate change series while many more advanced techniques have been reported in literatures, such as regional climate models or statistical downscaling methods. In addition, all days in the year undergo the same changes while climate models provide monthly changes. So, this can hardy be called a climate change study, rather a climate sensitivity study. Since there is a strong seasonality in the region, it is important to account for the seasonalities in the projected climate change (dry season may become dryer even when the average rainfall increases).

Response: We have now considered your comments and addressed accordingly by assessing the changes in water budget parameters, mainly discharge, as a function

of the change in rainfall and air temperature emanating from the climate changes at a larger scale (Table 5). We agree it is now a hydrologic sensitivity study due to the changes in climate variables.

Recommendations:

(1) Include a good literature review, including hydrological studies in the Mara, climate and land use studies in the region etc.

Response: This has been done

(2) Better describe the hydrology of the SWAT model, the curve numbers etc. Merge section 2.4 and 2.2

Response: This has been done

(3) Better describe the sensitivity and calibration methods. Which parameters have been changed and how? There are many parameters, and they are distributed.

Response: This has been done. The sensitivity analysis was carried out using the LH-OAT method. The calibration was carried out using the ParaSol and SUFI-2 methods. The parameters that were changed are shown in the Table 6.

(4) Include scenarios with irrigation developments

Response: From the field observations, type of crops grown, climate of the region, topography, size of the farms, and conclusions arrived to from the discussions held with the experts, irrigation is not particularly economically and logistically feasible in the upper Mara. This is not common in the area and there are currently no plans underway for any irrigation schemes. Irrigation was therefore not a plausible scenario in this study.

(5) Improve the calibration/validation results, or alternatively, evaluate the individual land use hydrology by experts (hydrologists) by comparing the hydrological components, the ET values, biomasses etc. Are these results logic?

Response: This has been done. See Table 7.

(6) Use better climate downscaling techniques, or, as a minimum, implement climate change scenarios on a monthly basis so that also minimum flows can be evaluated.

Response: this has been done and the scenarios used are based on the IPCC's Regional averages of temperature and precipitation projections from a set of 21 global models in the MMD for the A1B scenario for East Africa as described in the methodology section and shown in Table 5.

(7) Show the hydrographs (observed versus simulated)

Response: this has been done and added to the document.

(8) Account for the comments below.

Specific comments:

- Improve the description of the case, more emphasis on the 2 tributaries that have been studied.

Response: The focus of the study was shifted to one tributary the Nyangores River which is the focus of this study.

Locate the gauging station on figure 1.

Response: this has been done and it can be located in Figure 1 as LA03

– Improve the description of the land cover classification so that non-specialists can understand it. Eg. "Spectral values' in line 3 and 'reflectance data' in line 4 refer to the same data?

Response: that has been removed and the description has been improved.

How were the classes (line 7) defined? I guess by experts as described later but in that case, describe the actions in the right sequence.

Response: This has been described in the text.

- The paper describes the river Mara, but eventually looks at the rivers Amala and Nyangores only.

Response: The study is based in the Mara basin and looks at the Nyangores River which is one of the two main tributaries that form the Mara River. Unnecessary emphasis on the Mara basin has been reduced and the remainder is made only for the purpose of highlighting the importance of these headwater tributaries and what the impacts of land use and climate change in these watersheds would imply for the system as a whole.

- Page 5859, line 21 mentions years calibration + 2 years validation for the RFE model, while in page 5860, 2 years are mentioned.

Response: The disparity between the rain gauge and RFE rainfall resulted in different periods for calibration and validation based on availability of rainfall and discharge data.

- Use more logic titles for the scenarios: partial deforestation converts to agriculture while complete deforestation converts to grassland, so I would call them (1) partial deforestation, conversion to agriculture PDA (3) complete deforestation, conversion to agriculture CDA (2) complete deforestation, conversion to grassland CDG

Response: This has been done and the scenarios have been titled accordingly.

- How were the land use classes in the SWAT model parameterized? The SWAT crop data base only contains US data.

Response: Table 2 explains how the land use was parameterized.

- Use less significant numbers for the K statistics. What does it means? % that was classified correctly in validation?

Response: less significant numbers have been used for the K statistics. Kappa or k statistics provides a measure of the degree to which actual and classified land cover

data concur.

- Line 3 of page 5864: what is meant with parameter 'adjustment'? - What was the model bias? Technical comments

Response: Parameter adjustment in this case means the adjustment of the parameter values in the manual calibration process in order to better fit the observed data to the simulated data. Care is taken to make sure that these parameter values stay hydrologically realistic.This however was not done when the new algorithms were used.

- Please refer to the figures (figure 1-6 are not referred to!),

Response: This has been done

also line 5865 does not mention which graph?

Response: addressed

- Some splitting is very unfortunate eg 5855 line 3, 5853 line 8

Response: it was part of the HESS formatting during page layout

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/7/C4521/2011/hessd-7-C4521-2011-supplement.pdf

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Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 7, 5851, 2010.