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Discussions

Interactive comment on "Scenario-based impacts of land use and climate changes on the hydrology of a lowland rainforest catchment in Ghana, West Africa" *by* Michael S. Aduah et al.

Michael S. Aduah et al.

msaduah@umat.edu.gh

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Interactive comment on "Scenario-based impacts of land use and climate changes on the hydrology of a lowland rainforest catchment in Ghana, West Africa" by Michael S. Aduah et al.

Anonymous Referee #1

Major comment 1: The manuscript "Scenario-based impacts of land use and climate changes on the hydrology of a lowland rainforest catchment in Ghana, West Africa" by Aduah et al. deals about the separate and combined analysis of impacts due to

climate and luse use change using the ACRU model. For this, a calibrated model for the Bonsa catchment was used (Aduah et al., 2017, companion paper). In general, impact studies for African catchments are of broad interest since adaptations plans regarding water management for the future will be necessary in the context of climate change. Hydrological or ecohydrological models can be a useful tool to support management decisions. However, the usefullness of model results strongly depends on a reasonable application of the models and a thorough analysis of the model results. In this regard I have two main concerns that need to be addressed or clarified by the authors:

1. All presented results are based on modelled monthly streamflow. Model calibration was presented in a companion paper. It was reported that "validation based on the daily time step did not generate satisfactory performance as NSE of 0.14 and 0.31 were obtained during calibration and validation, respectively". As a consequence monthly time steps were used since performance was better.

In my opinion, it is not good modelling practice to leave out poor model performance on a daily time step and to present satisfying model performance on a monthly basis. There must be a reason for poor model performance and in this regard, the authors need to clarify, if this poor performance may have implications for all following applications and conclusions. How can the authors be sure that hydrological processes are adequately simulated? Obviously there are not well simulated. Otherwise, model performance for daily time steps were much better.

Additionally it is not good modelling practice to use only a small number of performance measures, especially if all selected measures are focused on peak and high flow. I respect the circumstance that the investigated catchment may be not intensively monitored and that data scarcity may be a problem. However, there are additional ways to make sure that the model behaves reasonable and of course realistically (e.g. using constraints, rules-of-thumb, multi-site calibration, model output such as discharge components or hydrological components over time).

Response 1: The ACRU modelling was done at the daily time step and it would have been preferable to be able to undertake the analysis also at a daily time-step. However, the high levels of data uncertainty (limited rainfall, temp, gaps in streamflow spatially and temporally, etc) and constraints in the downscaling method applied to GCM data and the associated uncertainties in the Bonsa catchment (as discussed in Aduah et al, 2017) meant that a more acceptable time step for analysis was the monthly scale. Moriasi et al. (2007) show that if the Nash-Sutcliffe efficiency (NSE) index of between 0 and 1 indicates that model performance is generally acceptable, whereas a NSE of 0.5 and above indicates satisfactory model performance, whether at the monthly or daily time step. Thus, the NSE of 0.1 and 0.3 for the daily time step in the companion study does not necessarily indicate that the model performance in the Bonsa catchment was unacceptable; only that the model performance when analyzed at the monthly time step was better. Croke et al. (2008) highlight that higher resolution time steps, have the potential to have increased uncertainties. Thus, given the uncertainties in the input data due to the data scarcity in the catchment, analysis of modelling results at a monthly time step was deemed acceptable as it reduced uncertainty. It must be noted that the NSE was not the only performance measure used; several others, including differences between the means, standard deviations and graphical analysis of the time series (Aduah et al., 2017) which are not focused on the peak and high flows, were used and the current manuscript has been modified to include percent bias (PBIAS) statistic at the daily time-step, for model evaluation. However, multi-site calibration was not possible due to the lack of data, however, a sensitivity analysis was undertaken in the companion paper (Aduah et al., 2017) to assist in ensuring that the simulation was realistic. As the uncertainties in the poor data are reduced at a coarser time step, the authors believe that the monthly analysis of the modelling results is acceptable.

References Aduah, M. S., Jewitt, G. P. W., and Toucher, M. L. W.: Assessing suitability of the ACRU hydrological model in a rainforest catchment in Ghana, West Africa, Water Science, https://doi.org/10.1016/j.wsj.2017.06.001.

Moriasi, D. N., Arnold, J. G., Van Liew, M. W., Bingner, R. L., Harmel, R. D., and Veith, T. L.: Model evaluation guidelines for systematic quantification of accuracy in watershed simulations, Transactions of the Asabe, 50, 885-900, 2007.

Croke, B. F. W., Wagener, T., Post, D. A., Freer, J., and Littlewood, I.: Evaluating the information content of data for uncertainty reduction in hydrological modelling, 9th International Congress on Environmental Modelling and Software, 2008.

Major Comment 2: Due to coarse temporal resolution, all derived conclusions do have a more general character such as "wetter" or "longer dry periods". I wonder if this is really a good basis to develop management plans for a catchment. Other short-time effects such as flood events or extreme precipitation events cannot be considered at a monthly scale. Consequently, it is impossible to discuss implications of those events on agriculture or humans even if they might be more relevant than the general tendencies that are presented. Leaving out daily resolution might be also the reason for more or less similar tendencies for all climate scenarios. Based on the previous points, I do not share the opinion that this study provides a platform for further studies since high uncertainties are given due to methodical limitations (monthly resolution, exclusion of additional model output for further analyses).

Response 2: (Line 330 in revised manuscript). In the absence of any studies, we believe the information provided in this study will be useful to planners. We agree that floods/extremes will be useful, but given the high levels of uncertainty, we are reluctant to provide information of this nature at this stage. Hence, the longer time scales and more general statements were accepted as what could be offered by this study. We follow this approach because we are reluctant to suggest that current daily time-step output are useful for management/planning because of the uncertainties that exist now, but that monthly time-step analysis of the modelling results provide initial useful information which can be further unpacked in future at a daily time step, as improvements in driver data (e.g. satellite, improved monitoring etc) and in output from GCM downscaling, becomes available. Furthermore, the change factor method

of downscaling GCM climate projections has limitations which mean that it could only be applied at a monthly time scale. The conclusions reached in this study are therefore first statements about potential impacts of climate change and land use changes on hydrology and are thus useful since this is the first study on combined climate and land use change in the rainforest region of West Africa.

In the following there are some minor comments:

Comments: L.34: I wonder if there are no recent studies that underline these statements. Examples are: Gloria Salmoral, Bárbara A. Willaarts, Alberto Garrido, Björn Guse, Fostering integrated land and water management approaches: Evaluating the water footprint of a Mediterranean basin under different agricultural land use scenarios, In Land Use Policy, Volume 61, 2017, Pages 24-39, ISSN 0264-8377, https://doi.org/10.1016/j.landusepol.2016.09.027.

Pablo A. Mendoza, Naoki Mizukami, Kyoko Ikeda, Martyn P. Clark, Ethan D. Gutmann, Jeffrey R. Arnold, Levi D. Brekke, Balaji Rajagopalan, Effects of different regional climate model resolution and forcing scales on projected hydrologic changes, In Journal of Hydrology, Volume 541, Part B, 2016, Pages 1003-1019, ISSN 0022-1694, https://doi.org/10.1016/j.jhydrol.2016.08.010. Hartwich, J., Schmidt, M., Bölscher, J. et al. Environ Earth Sci (2016) 75: 1071. https://doi.org/10.1007/s12665-016-5870-4

I am pretty sure that there are many other studies that may be cited here.

Response: Comments are accepted. More recent references have been included in the introduction section.

References added Guzha, A. C., Rufino, M. C., Okoth, S., Jacobs, S., and Nóbrega, R. L. B.: Impacts of land use and land cover change on surface runoff, discharge and low flows: Evidence from East Africa, Journal of Hydrology: Regional Studies, 15, 49-67, https://doi.org/10.1016/j.ejrh.2017.11.005, 2018.

Mwangi, H. M., Julich, S., Patil, S. D., McDonald, M. A., and Feger, K.-H.: Rel-

ative contribution of land use change and climate variability on discharge of upper Mara River, Kenya, Journal of Hydrology: Regional Studies, 5, 244-260, https://doi.org/10.1016/j.ejrh.2015.12.059, 2016.

Veettil, A. V., and Mishra, A. K.: Water security assessment using blue and green water footprint concepts, Journal of Hydrology, 542, 589-602, https://doi.org/10.1016/j.jhydrol.2016.09.032, 2016.

Comments: L.49: I would use K as unit. Response: The degree unit (line 51 of revised manuscript) has been changed to K.

Comments: L.174: It seems very vague to me, if "Temporal Dynamics" is the right term for monthly and annual discharge.

Response: The comment is accepted. Sections 3.1.1 and 3.2.1 headings have been changed to “Temporal Patterns”. The sections show annual and seasonal differences over time, hence the description as temporal patterns.

Comment: L.180: Does this finding indicate that a daily resolution is appropriate to reduce model uncertainty?

Response: Daily simulation was done, but due to uncertainties, the analysis of the results was done at the monthly time-step (line 220 in revised manuscript).

Comments: L.186: It would be interesting to see if there are additional negative impacts on agriculture (e.g. higher floods, extreme precipitation) that limit the agricultural productivity. Since this analysis is based on monthly resolution, this aspect cannot be considered and consequently, the results are limited to more general statements (e.g. length of wet season).

Response: Yes, this is possible with the model, but confidence in the downscaled climate data to daily time-step (Kusangaya et al., 2017) means we chose not to do this analysis. However, the more general statements on the impacts on agricultural productivity are still useful as the rain-fed agriculture in Ghana is sensitive to changes

in the wet season as highlighted by, e.g. Anim-Kwapong and Frimpong (2005) for cocoa and Jalloh et al. (2013) for crops in West Africa (please see line 226 in revised manuscript).

References Anim-Kwapong, G. J., and Frimpong, E. B.: Vulnerability of agriculture to climate change- impact of climate change on cocoa production Cocoa research institute of Ghana, New Tafo Akim, Ghana, 2005.

Jalloh, A., Faye, M. D., Roy-Macauley, H., Sérémé, P., Zougmoré, R., Thomas, T. S., and Nelson, G. C.: Overview, International Food Policy Research Institute(IFPRI), Washington, DC, USA, 1-36, 2013.

Kusangaya, S., Warburton, M., and Archer van Garderen, E.: Use of ACRU, a distributed hydrological model, to evaluate how errors from downscaled rainfall are propagated in simulated runoff in uMngeni catchment, South Africa, Hydrological Sciences Journal, 62, 1995-2011, 10.1080/02626667.2017.1349317, 2017.

Comment L.259-269: This part is not a discussion but a summary of the results.

Response: The comments are accepted. The section has been modified to explain the results (see line 299-305 in revised manuscript).

Comments L.287: Of course it is of advantage to consider additional aspects beyond the outlet streamflow to discuss climate change and land use change impacts. However, the authors left out other approaches such as having a look at model output (streamflow components, water balance).

Response: Comments about line 315(in revised manuscript) are accepted. However, if the available data had allowed analysis of the modelling output at a finer time scale, it would have been useful to consider these, but due to the uncertainties created and the limitation of the change factor method of downscaling climate projections, it was not done. The manuscript has been modified to include these as recommendations (see line 365-367 in revised manuscript).

Comment L.294: I do not share the opinion that this study provides a platform for further studies since high uncertainties are given due to methodical limitations (monthly resolution, exclusion of additional model output for further analyses).

Response: The phrase “provides a platform for further studies” has been maintained in the manuscript (line 330, revised manuscript). This is because the ACRU model is capable of running at a daily time-step, but that analysis for this study was at a monthly resolution. Therefore as the data becomes available, the analysis can also take place at a daily time-step. Hence this study does provide a platform for further studies. Please refer to Response 2 on page 2 for further discussion on this.

Comments L.329: In this regard I am not with the authors since model performance was evaluated with only a small number of performance measures and only for monthly resolution at a single gauge. Consequently, I do not see a satisfactory calibration.

Response: (line 365-367 revised manuscript). Percent bias (PBIAS) at the daily time-step (-.3.8% and -15.6% for calibration and validation, respectively) has been included in the model evaluation in the manuscript, which further indicates that the modelling at the daily time-step was not unacceptable, only that the analysis at the monthly resolution produced better statistics. Please refer to Response 1 on page 1, which addressed the Major comment 1 for a further discussion on this.

Comments on figures and tables:

Comment: Fig.4: very unsharp, needs to be integrated in a higher Resolution Response: Resolution of Figure 4 has been improved.

Comment: Fig.5: Why do the authors scaled up to 3000 m3/month? 1500 would be enough and would allow having a closer look at the discharge. Please be consistent with scale resolution (e.g. fig a,b). It should be mentioned that it is modelled discharge.

Response: Scaling of Figure 5 has been reduced to maximum 1500 m3/month

Comment: Fig.6: I do not understand the term "1 in 10 year high".

Response: To aid in clarity, both the terms “1 in 10 year high” and “1 in 10 year low” have been removed from Figure 6.

Comment: Fig.9: Information in the right upper part is already given in the caption

Response: The caption of Figure 9 has been corrected. 90th and 10th percentile have been removed from the figure caption.

Comment: I hope that the authors understand the listed comments as a recommendation to rework and improve some fundamental points of their manuscript. Hopefully, this study will be published after a major revision. I wish much success in this.

Response: The authors thank the reviewer for his/her comments. Each of the comments made has been given considered thought and responded to. We hope that the clarifications made and the justifications given address the reviewer’s comments adequately.

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