Hydrol. Earth Syst. Sci. Discuss., 12, C7005–C7025, 2016
www.hydrol-earth-syst-sci-discuss.net/12/C7005/2016/
© Author(s) 2016. This work is distributed under
the Creative Commons Attribute 3.0 License.

Hydrology and Earth System Sciences
Open Access
Discussions

Interactive comment on "Afforestation by natural regeneration or by tree planting: examples of opposite hydrological impacts evidenced by long-term field monitoring in the humid tropics" *by* G. Lacombe et al.

G. Lacombe et al.

g.lacombe@cgiar.org

Received and published: 28 March 2016

We thank the third anonymous referee for the constructive comments that helped us improving the article. Here below, we have pasted all his/her comments and questions and have responded to each of them. 'Authors:' is written at the beginning of each of our responses. The number of Fig. 6 and Fig. 7 have been switched and correspond now to Fig. 7 and Fig. 6 in the discussion paper, respectively.

Anonymous referee 3

General comments The article presents an analysis of the trends in the hydrological features of two catchments under tropical conditions, linked to changes in land use. The authors use hydrological modelling to test the role of vegetation changes in the observed hydrological trends and explore a number of hypotheses to explain the differentiated behavior on the two catchments. The article is well presented. However I have some concern about the testing method-ology used by the authors. I found it difficult to fully understand what the authors did, and some choices seem unclear (see detailed comments below). I think this should be better explained/justified. Possibly some calculations should be redone with more appropriate method.

Detailed comments 1. The title might be shortened into: "Opposite hydrological impacts of afforestation evidenced by long-term field monitoring in the humid tropics"

Authors: we thank referee 3 for suggesting this title that we have selected for our article.

2. P12617, L12: Write"1-year periods" (and also elsewhere in the text, typically "1-year fallow")

Authors: '1-year period' was actually written in our manuscript originally submitted to the journal. We hope that this writing will be maintained when we submit the revised version. We did the necessary change for 'fallow'.

3. P12648, L27: Homogenize the way "streamflow" is written in the article.

Authors: 'stream-flow' and 'streamflows' were changed to 'streamflow'. 'flow' was replaced by 'streamflow' where it is appropriate.

4. P12619: It seems that the authors applied an existing testing methodology (based on hydrological modelling). This should be made clear in the introduction.

Authors: further to the changes made in the introduction in response to similar comments made by referee 1 (reported in our Author comment AC C6949), we have modified the second and third objectives at the end of the introduction as follows:

"2. Use a conceptual monthly lumped rainfall-runoff model repeatedly calibrated over successive 1-year periods and used in simulation mode with specific rainfall input to generate cross simulation matrices (Andréassian et al., 2003). These matrices are used to isolate the hydrological effect of rainfall variability from that of other environmental changes (e.g. land-use change, in this article) in each study catchment, 3. Apply correlation analyses and a non-parametric trend detection test to streamflow reported in the cross simulation matrices, to investigate and quantify causal relationships between land-use changes and changes in the hydrological behaviour of the study catchments, and assess whether the hydrological changes are statistically significant over the whole study period,"

5. P12623, L3-4: Is it useful to have this information here?

Authors: providing information on the mapping accuracy is useful because this mapping is used to assess the percentage area of each land-use unit which, in turn, evidences the causation between land-use change and change in hydrological behaviour.

6. P12624, L7-11: I was a bit surprised by this comment that the initial conditions at the beginning of April vary in such a limited range that they have no impact on the simulations and can be set to average values. It would mean that the dry period would act as resetting the memory of the catchment antecedent conditions and that whatever happens in March, there will be no impact on flow simulation in April. Setting the initial conditions at average values mean that no link between years is allowed. I found this is a strong hypothesis and I do not understand why the authors made such an assumption: it is useless since the model could be run with one year warm-up period.

Authors: by initially writing in our manuscript "These initial water levels were set to the inter-annual averages of values observed at the beginning of each hydrological year" (P12624, L10-11), we were referring to the initial values at the beginning of the whole study period, i.e. in April 2001 in Laos. No other reservoir water level adjustments were performed in the following years. Therefore, we confirm that our simulations allowed

flow continuity between successive years. The use of average values for the initial water levels of the model reservoirs in April 2001 (in Laos) allowed including the hydrological year 2001 in the flow simulation for comparison with the land use mapped in 2001. Having clarified this point, we agree that our previous approach (initial reservoir water levels in April 2001 set to the average values of the two reservoir water levels observed at the beginning of other hydrological years) may not be valid for the reason provided by referee 3. Therefore, we are now using the hydrological year April 2001 – March 2002 as a warm-up period to initiate the reservoir water levels of the model applied to the study catchment in Laos. Consequently, the new figures 5 a, b and 7 a, b do not include flow simulated in 2001 in Laos any more. We adjusted the text of the article accordingly and revised several values: the statistical significance of the cross-simulation test (now computed over the period 2002-2013), the correlations coefficients between simulated flow and land use, and the quantified hydrological changes. In Vietnam, flows have started being recorded in April 2000 (as now specified at the beginning of section 2.2), with a gap of 3 months between August and November 2001 (already mentioned in our discussion paper). The initial period (April 2000 – March 2002) includes 20 monthly flow values that were already used as a warm-up period for the first 1-year calibration starting in April 2002. The removal of the simulation year 2001 in Laos now results in greater consistency in our method because we are using exactly the same simulation period for the two study catchments in Laos and Vietnam (April 2002 – March 2013). This modification is also reported in the text where it is needed.

7. P12624, L11-12: The authors used one-year periods for calibration. This is very short, especially at the monthly time step. Hence the model parameters may be much dependent on the characteristics of the selected year. Is the model robust enough to avoid this dependency? I think the authors should (1) better discuss the stability of performances when going from calibration to validation and (2) analyze the sensitivity of their results to the length of the calibration period (if 2- or 3-year periods had been selected, would conclusions remain similar?).

Authors: to address this comment, we have changed the title of section 4.4. (formerly entitled “Concluding remarks”) to “Reliability of the results” and have rewritten the whole section as follows:

"A 2-parameter monthly lumped rainfall-runoff model was used to investigate the relationship between land use and catchment hydrology. This approach presents some limitations. For instance, land-use changes occurring within or outside of the riparian area and their hydrological effects were not differentiated. The spatial patterns of the land-use mosaics (e.g. area, layout and connectivity of the patches) were not accounted. This simplification limits our understanding of the processes underlying the rainfall-runoff transformation. However, the model efficiently captured the gradual changes in the catchments' behaviour (mean values of NSEQ and NSElnQ > 86 per cent) which proved to be significantly (0.00<p-values<0.08) and consistently correlated to highly variable land-use patterns. It could be argued that 1-year calibrations are too short for the model to accurately capture the hydrological behaviour of the catchment. This statement would be valid in the context of a more classical split-sample test including a calibration and a validation period where the model is used as a predictor. This procedure assumes that the catchment is hydrologically stable over these two sub-periods. In our approach, the rainfall-runoff model was used to capture gradual changes in hydrological behaviour in order to verify if these changes are caused by actual changes in land-use conditions. With this aim, minimizing the duration of the calibration periods to one year allowed maximizing the dependency between the model parameters and the corresponding land-use patterns mapped annually. This approach proved to be appropriate given the high inter-annual variability of land use (Fig. 5 and 6), and the significance of the correlations between land use and streamflow simulated with the different calibrated models (Fig. 5, 6, and 7). However, a one-year calibration may result into a model that performs well under the specific climate conditions of the calibration year only. Simulation biases usually increase when the model is run under climate conditions different from calibration conditions (Coron et al. 2012), thus possibly hampering the detection of the hydrological changes illustrated in Fig. 5 and

6. To quantify this bias, GR2M was calibrated over the two-year period (2012-2013) in the Dong Cao catchment where land use remained relatively stable between 2011 and 2013 (Fig. 6c). The rainfall years 2012 and 2013 correspond to the median (1421mm) and the wettest (1938mm) years, respectively, of the study period (2002-2013) (Fig. 4). Therefore, this two-year period exhibiting stable land use but contrasting rainfall conditions is well suited to investigate the effect of rainfall variability and calibration duration on model efficiency. The mean relative difference between streamflow simulated by this model and by the models calibrated over the 1-year periods 2012 and 2013 (the 3 models use the same 2012 year as rainfall input) approximates this simulation bias which was found to be higher for the wet season (20 per cent) than for the dry season (2 per cent). Overall, these biases are negligible compared to the major hydrological changes observed in the two study catchments: 67 per cent wet season streamflow reduction and 84 per cent dry season streamflow reduction over the study period in the Dong Cao catchment; 100 per cent wet season streamflow increase and 650 per cent dry season streamflow increase in the Houay Pano catchment between 2007 and 2011. In contrast, wet season streamflow over the period 2002-2006 in the Houay Pano catchment (Fig. 5a) exhibits the lowest inter-annual variations for a 5-year period in the study catchments, with a coefficient of variation (11 per cent) lower than the 20 per cent bias estimated for the wet season simulations, indicating a possibly significant modelling artefact. However, these streamflow variations are significantly and consistently correlated to land-use change over this short period (Fig. 7a), suggesting negligible biases even for these slightest streamflow variations. The main discrepancy between simulate streamflow and land use was observed during the 2009 wet season in the Dong Cao catchment. In 2009, simulated streamflow is equivalent to about one third of that in 2008 and 2010, while no major change in land use apparently explains this drop. This discrepancy could originate from a simulation bias because 2009 was the driest year of the study period (Fig. 4)."

Authors: in addition to the above-comments now appearing in the article, we would like to specify that we had initially calibrated GR2M over 2-year sliding windows (moved by 1 year between each calibration), thus resulting in eleven calibrated models corresponding to the periods 2002-2003, 2003-2004, . . . , 2012-2013. The correlation coefficients between hydrological behaviour (i.e. flows successively simulated with the 11 calibrated models using the same 2-year rainfall input), and land-use changes were less significant than those obtained with 1-year calibrations and reported in the article. This observation indicates that inter-annual changes in catchment behaviour are mostly influenced by the inter-annual variability in land use, thus justifying the selection of 1-year periods for our calibrations.

8. P12624, L14-16: This part is unclear for me. If I understood well, for each one-year period, the authors calibrated the model twice: once with NSEQ for the wet season and once with NSElnQ for the dry season. Is it the case? If yes, I have some doubt about this approach. It means that each parameter set was calibrated on six months, i.e. only six data, which reinforces my previous comment. Besides, prior transformations on flows are useful to make errors at various flow levels be in the same range, typically to make errors calculated on low flows be comparable to errors in high flows. If calculations are made on separate flow ranges, then the usefulness of these prior transformations is very limited. If this is not what was done, then this part should be better explained to fully understand what the authors did. Alternatively, a multi-objective approach may be more appropriate.

Authors: we confirm that each efficiency criterion was calculated with the 12 monthly values of the one-year calibration period. This is now made clear in the text:

"The Nash-Sutcliffe efficiency criteria calculated on flow (NSEQ) and calculated on the logarithm of flow (NSElnQ) were used for the evaluation of wet and dry season streamflow simulations, respectively. While each of these two efficiency criteria are calculated with the 12 monthly flow values of each 1-year calibration period (including wet and dry season streamflow), NSEQ and NSElnQ give more weight to high and low flow values, respectively. Therefore, the former and the later are suitable for evaluating high and low flow simulations, respectively (Pushpalatha et al., 2012)"

9. P12624, L14-16: Which calibration algorithm was used?

Authors: we have indicated in the text that the nonlinear Generalized Reduced Gradient method was used to determine the values of the two model parameters that maximize the efficiency criteria.

10. P12624, L18-19: How this constraint was applied in practice during calibration? Was there a weight attributed to bias in the objective function? Are there cases where this constraint could not be achieved?

Authors: the constraint was systematically successfully applied using a Branch and Bound method as indicated now in the text.

11. P12624, L19: What “calibration methods” refers to? The two objective functions? This should be clarified.

Authors: “calibration methods” has been changed to “objective functions”.

12. P12624, L29: Maybe write “Flow variations between columns for a given row. . .”

Authors: This is done and we made the same clarification in the following sentence: ‘Flow variations between rows for a given column’.

13. P12625, L2-8: I am sorry but I was completely lost in this part. Why this correction coefficient is used? What for? How can it generate an error interval? Please provide more details, explanations or references, else it is very difficult to understand.

Authors: we had initially introduced this correction coefficient to account for the possible simulation bias created when a model is run under climatic conditions significantly different from calibration conditions. This bias is likely to become significant when the model is calibrated over short periods like in our study. However, we have decided not to use this correction coefficient calculated with a formula that is not specifically validated for our study catchment. Instead, we now estimate and discuss the possible effect of this bias, using site-specific data in section 4.4 of the discussion (cf. our response to comment 7). The withdrawal of this correction coefficient has resulted in revised values of correlation coefficients and hydrological changes in the figures and in the text describing the results obtained for the two study catchments.

14. P12625, L5: Rainfall is noted R here while it is noted P in Figure 3. Be consistent in notations.

Authors: P was changed to R in figure 3 and in its caption.

15. P12625, L9-10: Please better explain what is shown in Figure 5. At first sight, it may look like a hydrograph, but actually it is not: if I understood well, it only shows for each year the simulated flow with the median rainfall using the model calibrated on that year. Hence drawing lines between points may lead to wrong interpretation. The fact that observed flows are also plotted tends to indicate that one could compare the observed and simulated values, but they were not obtained with the same rainfall input (except for the selected rainfall year) so they are not comparable. If I understood wrongly, this should be better explained.

Authors: This comment is correct. We have clarified the text as follows:

"Variations in simulated streamflow between the columns of the matrices were plotted against time. In these simulations, rainfall input to the model is similar each year and corresponds to the year with actual rainfall exhibiting median annual depth over the study period (years 2004 in Laos and year 2012 in Vietnam, cf. Fig. 4). The inter-annual variations in simulated streamflow illustrate changes in the hydrological behaviour of the study catchments under stable rainfall conditions (Houay Pano catchment in Fig. 5 a, b and Dong Cao catchment in Fig. 6 a, b). The objective of this simulation protocol is to isolate the hydrological effect of rainfall variability from that of other environmental disturbances and verify the hydrological influence of actual land-use changes by comparing Fig. 5a, b and Fig. 6a, b with Fig. 5c and Fig. 6c, respectively, showing temporal variations in land-use patterns."

Authors: We also modified fig. 5 and 6 to avoid possible misinterpretation of continuous flow time series between years. In the new figures, simulated flows are represented by histograms which also better reflect the fact that each annual value is an annual average. We also removed actual flow values which are not useful in Fig. 5 and 6 and already drawn in Fig. 4. The new figure captions are provided in our response to comment 26.

16. P12625, L11-13: Again, I do not understand why the authors used a single year to illustrate model results. If all simulations were plotted, how would it look like and how could this be interpreted?

Authors: our response to comment 15 addresses the first part of comment 16. Fig. 8 shows all wet season simulated flows reported in the cross simulation matrix for the Houay Pano catchment in Laos. One curve corresponds to one row in the cross simulation matrix (Fig.3), where all simulated flow values are simulated with the same year of rainfall input. The bold dotted curve corresponds to simulated streamflow shown in Fig. 5a, simulated with median rainfall. For a given calibration year (on the X-axis), streamflow differences between the different curves are due to the difference in rainfall input. For instance, the lowest curve was simulated using rainfall from the driest year of the period 2002-2013 (i.e. year 2009 shown in fig. 4a). The top curve was simulated using rainfall from the wettest year of the period 2002-2013 (i.e. year 2013 shown in fig. 4a). The purpose of our approach was to isolate the hydrological effect of rainfall variability from that of other environmental disturbance (for instance land-use change). But we did not aim to predict the catchment behaviour under a range of different rainfall conditions. For this reason, Fig. 8 will not appear in the article and was produced to answer comment 16 only.

17. P12626, L10: “increases”

Authors: done

18. P12626, L20-22: How this can be interpreted? Calibration and validation perfor-

mance should be distinguished to better evaluate model robustness (see comment 7). Note that performance criteria between years are sometimes difficult to compare due to the dependency of NSE values to the observed variability of flows (see e.g. Martinec and Rango, 1989).

Authors: see our response to comments 7.

19. P12626, L20-22: See comment 15

Authors: we agree that previous wording was ambiguous, suggesting possible continuity in simulated flows over years. In response to another comment made by referee 1, we already modified the text which has removed this ambiguity.

20. P12628, L7-9: Same as comment 18

Authors: see our response to comments 7.

21. Section 4: The discussion of results should be checked in light of the previous comments.

Authors: we have significantly extended the discussion section. Cf. our response to comment 7.

22. P12631, L29: Avoid unnecessary precision (e.g. 165 000 instead of 165 004 is probably precise enough)

Authors: done

23. Section 4.4 could be renumbered into Section 5 and extended as a proper conclusion. Some conclusions may change given the comments made above (check also the abstract).

Authors: the former section 4.4 was rewritten (cf. our response to comment 7). The two paragraphs of the former section 4.4 (Concluding remarks) have been moved to a proper conclusion section (section 5). The abstract was checked and no major change

is required.

24. P12635, L2-4: The high model efficiency in calibration may partly be due to the fact that very short periods were used to calibrate the model, therefore making it is easier to get high performance. It should be checked that the loss of efficiency from calibration to validation is not large. The error level of the model should be compared to the trends the authors want to show.

Authors: as indicated in our response to comment 7, the model is used to capture the hydrological behaviour of the catchment year by year, and to analyse how this hydrological behaviour varies between years. It is therefore not necessary and not possible to validate the model since the land-use pattern is changing every year. The high model efficiency mentioned in the text is referring to its ability to capture the hydrological behaviour of the catchment over a single year with the adjustment of only 2 parameters. We modified the text at the beginning of section 4.4 to better reflect this statement:

"However, the model efficiently captured the gradual changes in the catchments' behaviour (mean values of NSEQ and NSElnQ > 86 per cent) which proved to be significantly (0.00<p-values<0.08) and consistently correlated to highly variable land-use patterns".

25. P12635, L12-14: This is probably a necessary but not sufficient condition.

Authors: The sentence, now included in the conclusion (section 5) has been modified as follows:

"Our analysis demonstrates that this other category of models necessarily needs to account for changes in soil properties following land conversions in order to efficiently simulate the hydrological effects of land-use changes."

26. Figs. 5 and 7: Please make clear in the caption what is shown on the graphs (x axis = calibration year). I still do not understand why the shaded interval would correspond to an error interval.

Authors: The captions of the figures and the figures themselves were modified to address the two points raised by the referee. As an example, we provide here the new caption of fig. 5:

Figure 5. Houay Pano catchment, Laos. Wet season (a) and dry season (b) streamflow simulated with GR2M calibrated each year (indicated on X-axis) and ran with the same rainfall input. (c): cumulative percentages of surface area of each land-use unit.

Authors: We also removed the error interval materialized by the shaded area for the reason mentioned in our response to comment 13.

27. Fig. 6: What is the significance of the regression coefficients given the sometimes very limited number of points used?

Authors: The F-test p-value of each linear regression is now indicated in the figure.

Cited reference Martinec J., Rango A. (1989) Merits of statistical criteria for the performance of hydrological models. Water Resources Bulletin 25:421-432.

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 12, 12615, 2015.

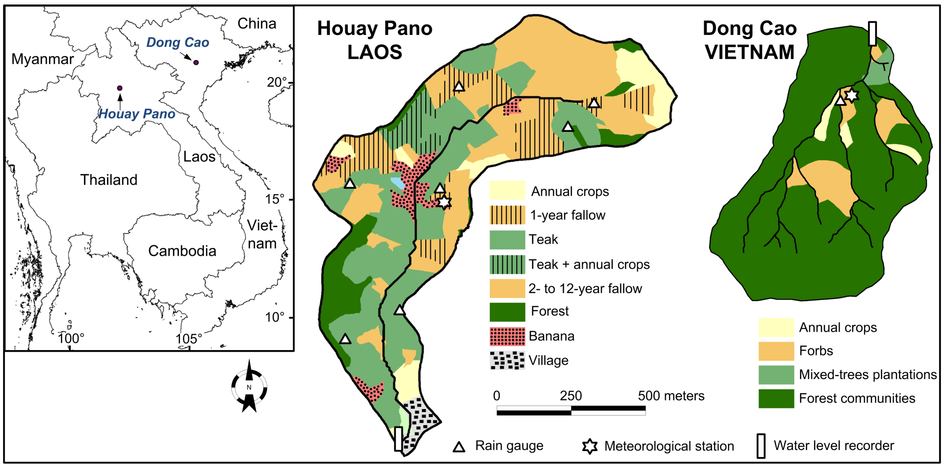

Fig. 1. Revised Figure 1 of the original discussion paper

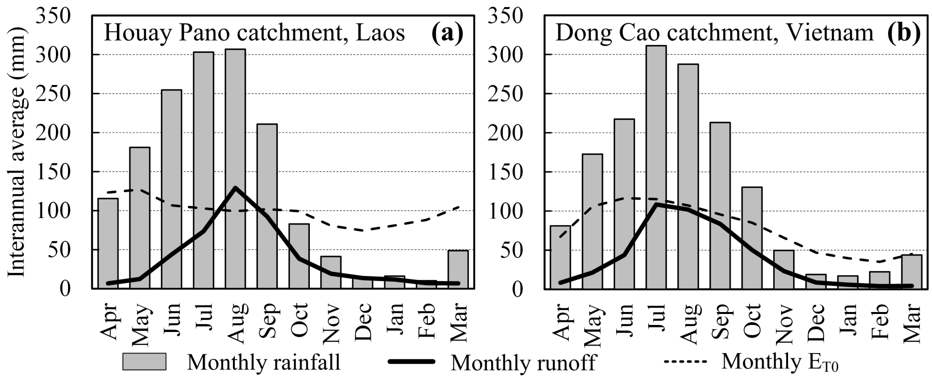

Fig. 2. Figure 2 of the original discussion paper

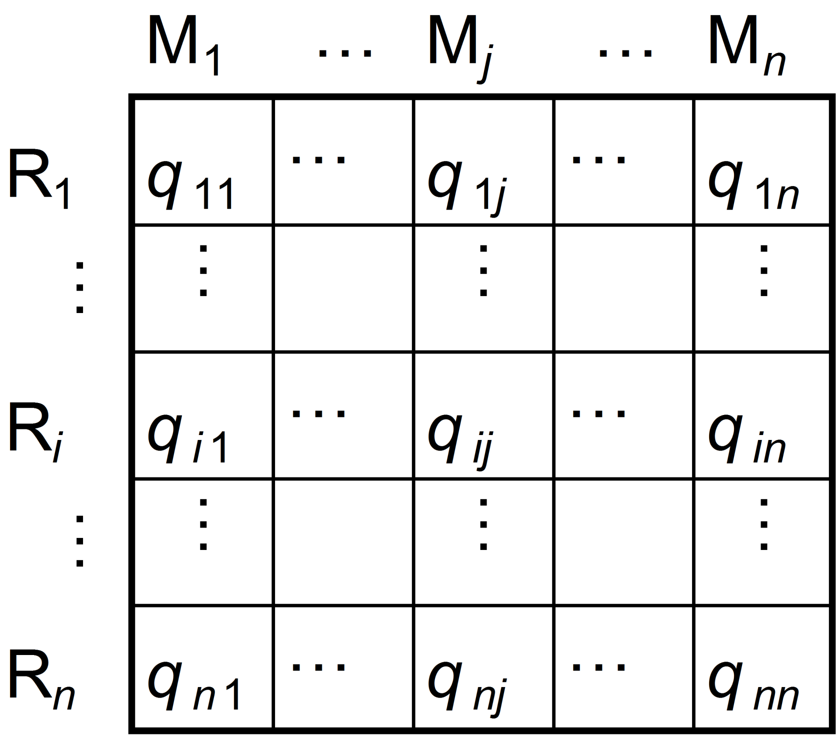

Fig. 3. Revised Figure 3 of the original discussion paper

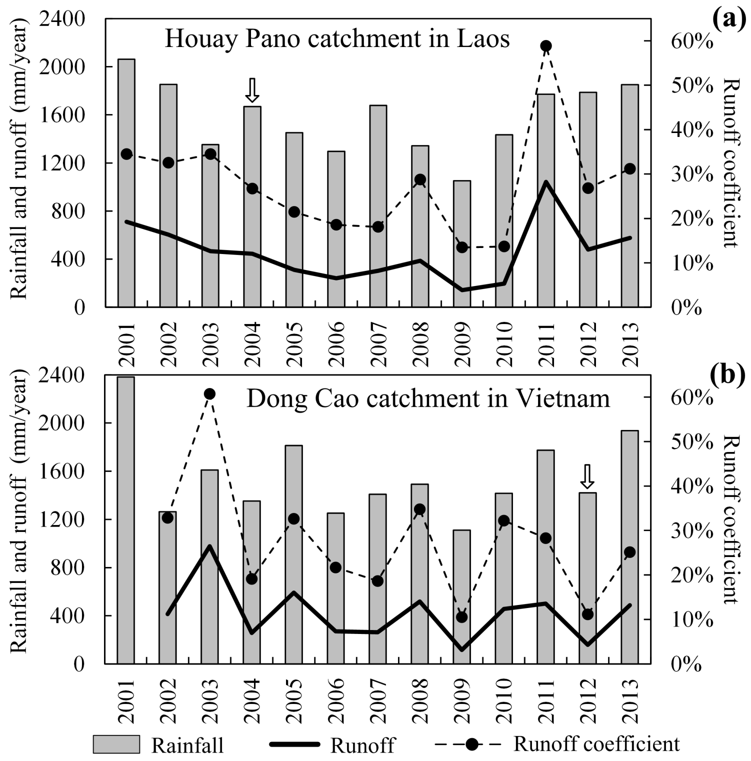

Fig. 4. Figure 4 of the original discussion paper

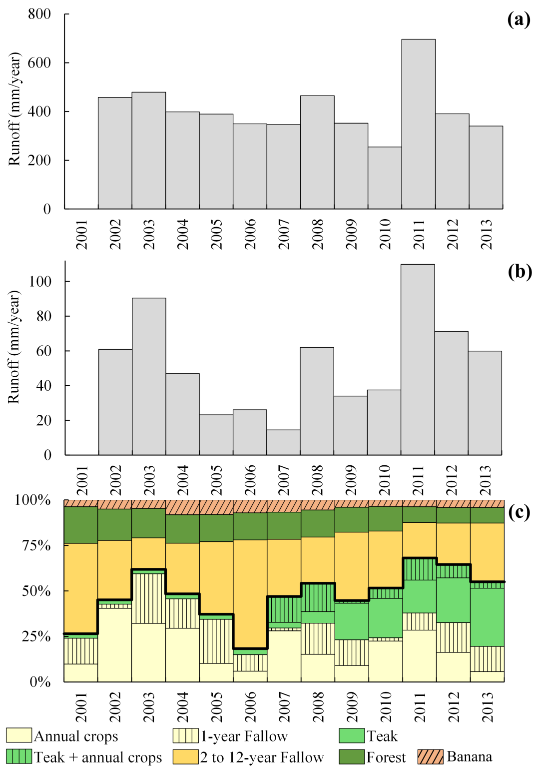

Fig. 5. Revised Figure 5 of the original discussion paper

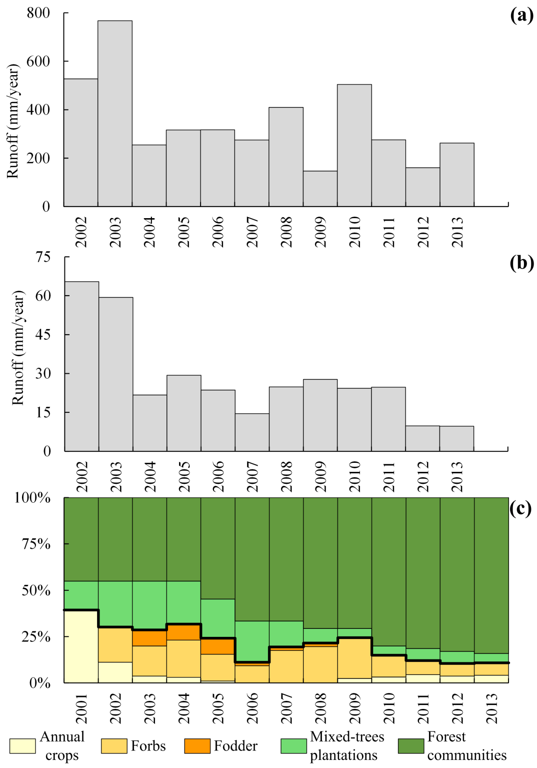

Fig. 6. Revised Figure 6 that was numbered 7 in the original discussion paper

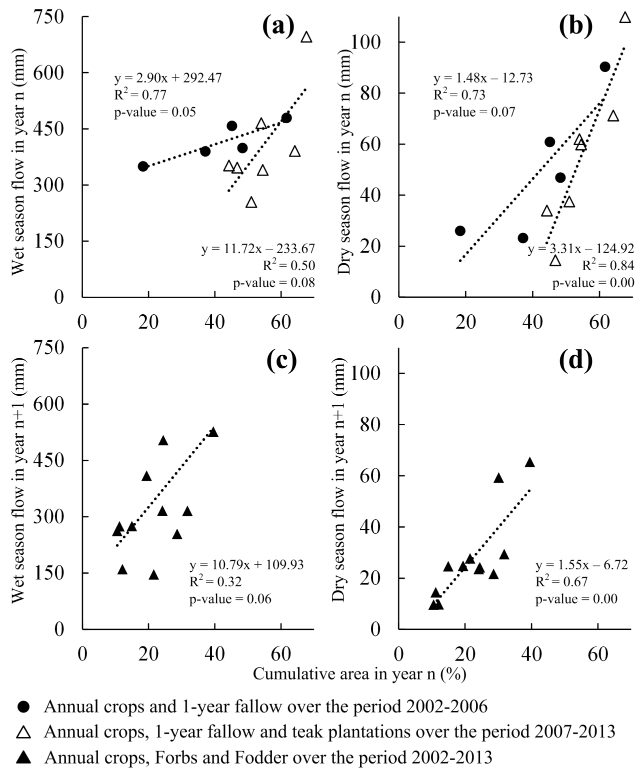

Fig. 7. Revised Figure 7 that was numbered 6 in the original discussion paper

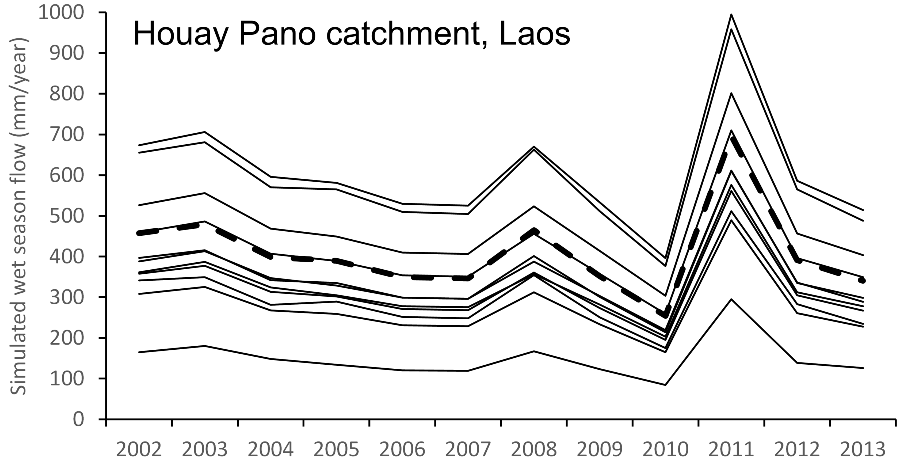

Fig. 8. Figure 8 drawn to answer comment #16, not to appear in the revised article