

Hydrol. Earth Syst. Sci. Discuss., author comment AC1
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Reply on RC1

Yunfan Zhang et al.

Author comment on "Drought-induced non-stationarity in the rainfall-runoff relationship invalidates the role of control catchment at the Red Hill paired-catchment experimental site" by Yunfan Zhang et al., Hydrol. Earth Syst. Sci. Discuss.,
<https://doi.org/10.5194/hess-2021-5-AC1>, 2021

Response to Reviewer #1

Thanks very much for your great efforts to assess our manuscript. We have studied your and reviewers' comments carefully and made corrections/revisions as suggested. In the following, we have detailed how these comments are raised and our responses and revision.

General comments:

- The results are clear and it's an interesting topic which indeed needs more attention. The main part of the analysis is only applied for the control catchment and not for the treated catchment; based on the assumptions that only the control catchment behaved non-stationary during drought. The primary objectives are based on the concept that a catchment may not show non-stationary rainfall-runoff relationships during changes in climate; this need to be introduced and discussed in depth in the manuscript.

A. Your hypothesis is based on the assumptions that only the control catchment behaved non-stationary during drought. Are you sure that this is the case and that it's fair to make this assumption?

B. The primary objectives are based on the concept that a catchment may not show non-stationary rainfall-runoff relationships during changes in climate. Can you add references stating that it's not "allowed" for a catchment to show non-stationary behaviour?

Reply: Thank you for reviewing our manuscript and for the insightful comments.

A. It has been proved that the prolonged drought caused the rainfall-runoff relationship changed in the control catchment in the manuscript. Regarding to the hypothesis, whether prolonged drought has altered the rainfall-runoff relationship in the treated catchment is not tested or made explicitly in the manuscript mainly due to two reasons. One is whether prolonged drought will lead to changes in the rainfall-runoff relationship is still controversial. Saft et al. (2015) examined whether interdecadal drought induces changes in the rainfall-runoff relationships in 158 catchments in south-eastern Australia according to annual rainfall and runoff records. It is found that protracted drought led to a significant shift in the rainfall-runoff relationship in 46% of the catchment-dry periods studied and a

globally significant change in the rainfall-runoff relationship in 34% of the catchment-dry periods. But, the rainfall-runoff relationship of a small part of catchments did not change significantly, even if they suffered from long-term drought. The other reason is that it will be difficult to validate that prolonged drought has altered rainfall-runoff relationship of treated catchment as there will be two drivers (i.e. prolonged drought and afforestation) and contributions cannot be separated or identified independently based on single catchment observations. Nonstationary assumption was only made and tested in the control catchment and we believe this is the only assumption can be tested and validated faithfully based on current understanding and observations. Therefore, we only stated that estimated changes in rainfall runoff relationship using three methods will be consistent if shift in rainfall-runoff relationship of the control catchment is restored. Whether prolonged drought has induced rainfall-runoff relationship change in treated catchment and how to separated were not conducted in the manuscript.

B: The primary concept is that climate variability rather than climate change will not lead to nonstationary rainfall-runoff relationship of a catchment. This is a basic consent for paired catchment method and also for the other two methods to separate the impact of vegetation change on runoff. Climate change can lead to changes in rainfall-runoff relationship of a catchment, such as prolonged drought.

- It's a flaw that the manuscript lacked detection of changes in the rainfall-runoff relationship for the treated catchment. Although it's obvious why there is a control and a treated catchment, I think it's important to apply the appropriate parts of the applied analysis for the treated catchment, also to have a better understanding of the underlying processes; to confirm or to deny the non-linear behaviour of the treated catchment.

A. If the treated catchment has not been reforested, did you expect the treated catchment to show similar behaviour as the control catchment?

B. Does the treated catchment already shows the same non-linearity as the control catchment?

Reply: Thanks for this insightful comment.

A. If the treated catchment has not been reforested, we expect the treated catchment to show similar behaviour as the control catchment. Because the terrain, meteorology, area of the two catchments are very similar, when the treated catchment is not reforested, the land cover types of the two catchments are also similar, both are grassland. When prolonged drought occurs, the change of hydrological process in two catchments should be similar.

B. Yes, the treated catchment shows the similar non-linearity as the control catchment, as shown in Figure R1 and Figure 5 (Page 39). But observed changes in treated catchment should be driven by two factors, i.e. afforestation and prolonged drought by assuming prolonged drought can lead to changes in rainfall-runoff relationship of the treated catchment.

According to reviewer's comments, rainfall-runoff relationship of the paired catchments and whether further assumption on the rainfall-runoff relationship change induced by prolonged drought can be made were re-examined and investigated carefully. We would like to make this further assumption as suggested and the new framework and methodology is stated in a separated document as attached. Methodology and results of the manuscript will be revised accordingly.

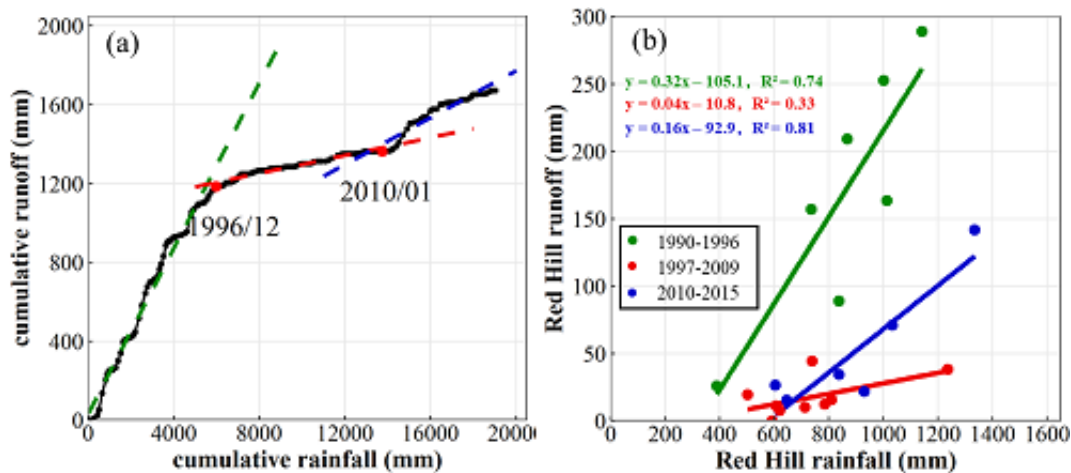


Figure R1 Double mass curve of monthly rainfall and runoff, and (b) Relationships between annual rainfall and runoff of the Red Hill catchment (treated catchment), New South Wales, Australia, during the period of 1990–2015. The dashed lines in (a) represent the linear regression lines between cumulative rainfall and cumulative runoff during the periods of January 1990 to December 1996 (green), January 1997 to January 2010 (red), and February 2010 to December 2015 (blue). The green, red, and blue lines in (b) represent the linear regression lines for 1990-1996, 1997–2009, and 2010–2015, respectively.

- You also may consider to add more information about the treatment (land use change), and the estimated changes in PET and rooting depth? The latter especially in introduction/area/ discussion. As a reader I do not find the evidence that the processes at the treated catchment did not changed.

Reply: Thank you for the constructive comment.

- During 1988 the uppermost 50 ha of Red Hill was planted to *p. radiata*, with the remaining 145 ha planted to *p. radiata* in April 1989. During 2003 the plantations in Red Hill catchment were thinned to remove pulpwood and to promote the growth of sawlogs in the remaining stands. During the prolonged drought period, no trees died in the treated catchment.
- The change of annual PET can be seen in Figure 8 (b) (Page 42). PET showed an insignificant (p -value > 0.1) increasing trend of 3.5 mm year^{-1} . PET initially decreased before 1996 and then increased after 1996. The mean annual PET during the period of 1990-1996, 1997-2009, 2010-2015 and 1997-2015 are 1168 mm, 1262 mm, 1186 mm and 1238 mm, respectively. Compared with the period of 1990-1996 and 2010-2015, the mean annual PET during the period of 1997-2009 (the prolonged drought occurred) increased by 94 mm and 76 mm, respectively. Compared with the period of 1990-1996, the mean annual PET during the period of 1997-2015 increased by 70 mm. It is consistent with the cognition that afforestation and drought can make PET increase.
- Unfortunately, there is no rooting depth data.
- The processes at the treated catchment changed, as shown in Figure R1.

In the revised manuscript, more detailed about the treated catchment will be provided.

- Figure 6 / Figure 8 / Area & Methods / results; It's not mentioned that before 1990 there was relatively more precipitation (Figure 2), which could have a major impact on your results because of the "memory" (storage) capacity of the catchment / soil's / geology.

Reply: Thank you for the constructive comment. We think that memory or storage capacity influences may not be noticeable enough to alter the conclusion of this study. Mainly due to four reasons.

- the paired catchments are similar and both are very close to each other and experienced same climate conditions before the treatment. Even though climate is relatively wetter before the availability of observations of these two catchments, influences of climate variability can be eliminated by paired catchment experimental setting.
- Precipitation before 1990s is wetter but not very much. In Figure 2 (Page 36), the mean annual rainfall during the period of 1983-1989 and 1990-1996 are 1120 mm and 1090 mm, respectively. The difference of rainfall between two periods is 30 mm. It indicates that there was relatively more precipitation during the period of 1983-1996.
- Influence of annual carry over soil storage on multiple year runoff is usually much smaller than annual rainfall variability. The time scale of data used in the three methods are all greater than or equal to monthly scale. And the Eq. (5), Eq. (8) and Eq. (9) are all based on data of annual scale (Pages 10-11), which can ignore the impact of water storage (soil moisture).
- Studies catchments are very small and storage memory effects should be small. The areas of these two catchments are small, the time scale of runoff generation and discharge is very fast, the impact of water storage on runoff may be small.

Therefore, we think that the influence of water storage ("memory" (storage) capacity) may be small.

- In lines 428-431 you write "The common assumption of the three methods is that the interaction between climate variability and vegetation changes in very small and can be ignored" and that "The total changes of runoff are a linear combination of runoff changes caused by climate variability and vegetation changes". What is your opinion about this assumption? And what does your results imply? And what does other literature states about the assumption and the linear combination?

A. I suggest to strengthen your paper to dive deeper in these assumptions about linearity. You already started with this by mentioning "only the sensitivity-based method uses the change of rainfall and potential evapotranspiration to obtain the runoff change caused by climate variability" (lines 436-438);

B. Does the statement in lines 436-438 imply that the other two methods are not suitable to apply in your case?

Reply: Thanks for this insightful comment. We think that assumption of neglecting interactions of climate variability and vegetation and linearity assumption are two ideal assumptions for separating changes caused by these two drivers. Based on these two assumptions, paired catchment method, time trend method and sensitivity-based method are derived and used widely to separate the effects of climate variability and vegetation change on water yield. Most of studies has shown that separated vegetation impacts using three different methods are very close and summation of the impacts of climate variability and vegetation change using independent methods are very close to 1.0 or 100%, for instance, Zhao et al. (2010) used all three methods in six paired catchments in Australia, South Africa, and New Zealand, and showed that the three methods had good consistency among all of the catchments. Zhang et al. (2011) applied the last two methods in a study of 15 catchments in Australia and demonstrated that both methods yielded differences of no more than 25%. These studies suggest that assumption of neglecting interactions of climate variability and vegetation and linearity assumption are acceptable and applicable. In reality, the feedbacks between forest and climate are relatively small at small spatial scale. The interactions between climate variability and vegetation change should be small

enough to be ignored compared with the individual effects of vegetation change and climate variability. Moreover, these feedbacks and interactions are very difficult to be observed.

A. Thanks for your helpful suggestions. It has been analysed in section 1 in the separated document as attached.

B. When considering the influence of prolonged drought on the rainfall-runoff relationship in the treated catchment, time-trend analysis method and sensitivity-based method overestimate the impact of vegetation change on runoff. The results of these two methods are actually the contribution percentage of prolonged drought and vegetation change as a whole to the runoff reduction in the treated catchment. It is difficult to separate the effect of prolonged drought and vegetation change using these two methods based on a single catchment. But they can be separated by applying time-trend analysis method to observed runoff of the control catchment (It can be seen in section 2 in the separated document as attached).

Specific comments:

- Although it's possible that title need to be edited after revision of the manuscript, at the moment the title is not entirely clear to me, "non-stationarity" "invalidates the role of control catchment" (I suggest something like: Drought-induced non-stationarity in the rainfall-runoff relationship dismisses valid comparison with the control catchment at the Red Hill paired-catchment experimental site);

Reply: Thanks for your helpful suggestions. Your suggestion will be considered seriously in the revised manuscript.

- Lines 94-95; "The other reason is related to the non-stationarity rainfall-runoff relationship of the control catchment". Do you mean that only the control catchment showed a nonstationary relationship? So the afforested catchment did show a stationary rainfall-runoff relationship? Be clear, because this is important information to have not only a proper understanding of the rest of the paper, but this also affects your hypothesis and objectives.

Reply: Thank you for the constructive comment and the helpful suggestion.

The rainfall-runoff relationship in the treated catchment also changed significantly. The change of rainfall-runoff relationship is mainly caused by vegetation change and prolonged drought. The detailed analysis can be seen in Comment 2. A flaw does exist in the hypothesis in the manuscript.

According to reviewer's comments, rainfall-runoff relationship of the paired catchments and whether further assumption on the rainfall-runoff relationship change induced by prolonged drought can be made were re-examined and investigated carefully. We would like to make this further assumption as suggested and the new framework and methodology is stated in a separated document as attached. Methodology and results of the manuscript will be revised accordingly.

- In line with previous comments, I suggest to rewrite the conclusion and abstract after additional analysis and new input on the assumptions

Reply: Thanks for your helpful suggestions. The new results base on the revised assumptions and methodology can be seen in section 3 in the separated document as attached.

Technical corrections:

- Line 31: "experimental site, using experimental observations", I would suggest to change the second "experimental" to "field" (or in-situ, if that is what you're pointing at);

Reply: Thanks for your advice. The second "experimental" will be replaced by "field" in the revised manuscript.

- Lots of repetitive information or sentences which can be shortened throughout the manuscript;

Reply: Thanks for your suggestions. Revised manuscript will be changed as suggested.

- In consequent reference of Fig. and Figure;

Reply: Thanks for your helpful suggestions. Changes will be made as suggested in the revised manuscript.

- Line 42; perhaps add a more recent paper;

Reply: Thank you for the constructive comment. Changes have been made as suggested. (see references below).

Wang, X.: Advances in separating effects of climate variability and human activity on stream discharge: An overview, *Adv. Water Resour.*, 71, <https://doi.org/10.1016/j.advwatres.2014.06.007>, 2014.

Dey, P., and Mishra, A.: Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions, *J. Hydrol.*, 548, <https://doi.org/10.1016/j.jhydrol.2017.03.014>, 2017.

Zeng, F., Ma, M., Di, D., and Shi, W.: Separating the Impacts of Climate Change and Human Activities on Runoff: A Review of Method and Application, *Water-Sui.*, 12, 2201, <https://doi.org/10.3390/w12082201>, 2020.

- Line 58; "paired-catchment method is based on paired-catchment experimental observations", I would suggest to change "experimental observations" to "field or in-situ observations".

Reply: Thanks for your helpful suggestions. "experimental observations" will be replaced by "field observations" in the revised manuscript.

- Line 59; perhaps add a reference to prove the "standard" approach;

Reply: Thanks for your suggestions. Changes will be made as suggested. (see references below).

Hewlett, J.: Comments on the Catchment Experiment to Determine Vegetal Effects on Water Yield, *JAWRA Journal of the American Water Resources Association*, 7, 376 - 381, <https://doi.org/10.1111/j.1752-1688.1971.tb05920.x>, 1971.

- Lines 62-67; references;

Reply: Thank you for the helpful suggestion. Changes will be made as suggested. (see references below).

Hewlett, J. D. (Ed.), *Principles of Forest Hydrology*, 183 pp., Univ. of Ga. Press, Athens, 1982.

Kirchner, J. W., Berghuijs, W. R., Allen, S. T., Hrachowitz, M., Hut, R., and Rizzo, D. M.: Streamflow response to forest management, *Nature*, 578, E12-E15, <https://doi.org/10.1038/s41586-020-1940-6>, 2020.

- Although it's not the "area" section, I do think you make your case stronger if you already mention the land use history of both catchments, as well as land use change during the evaluated measurement period.

Reply: Thanks for these constructive comments and helpful suggestions.

All catchments were substantially cleared of native vegetation during the 100 years prior to acquisition of the property by Forests NSW in 1988. At that time there was scattered timber in all two catchments but they were mostly covered with native grasses and some clovers. The remaining scattered native timber in Red Hill catchment was cleared in 1988 prior to plantation establishment. During 1988 the uppermost 50 ha of Red Hill was planted to *P. radiata*, with the remaining 145 ha planted to *P. radiata* in April 1989. A survey in 1997 revealed that productive stands occupied 78% of the Red Hill catchment. Aside from a small grove of native trees retained near the old Kileys Run homestead, the Kileys Run catchment has been maintained as a grass/pasture control. During 2003 the plantations in Red Hill catchment were thinned to remove pulpwood and to promote the growth of sawlogs in the remaining stands (Webb and Kathuria, 2012)..

Stocking rates in the Red Hill catchment remained relatively stable from 1994 to 1998 with only a small decline from 1416 stems/ha in 1994 to 1408 stems/ha in 1998. During that time mean DBHOB increased from 0.086 m to 0.163 m, while mean tree height increased from 5.15 m to 13.40 m. Basal area of the plantation stands increased from 8.1 m²/ha in 1994 to 29.4 m²/ha in 1998. Combined with stump measurements, predicted that basal area in 2003 prior to thinning was 40 m²/ha. The stands were heavily thinned with stocking rates reduced to <360 stems/ha and a modelled basal area of 10 m²/ha. Since thinning, the remaining stand has continued to grow. At age 16 (2005) the modelled basal area was 13.3 m² /ha and in 2009 at age 20 the measured stocking rate was 353 stems/ha with a mean DBHOB of 0.313 m, mean height of 23.09 m and basal area of 27.1 m²/ha (Webb and Kathuria, 2012).

- Line 105; what is the definition of much longer? Or even leave out "much".

Reply: Thanks for these helpful suggestions. "much longer" will be replaced by "longer". The length of data used in the manuscript increased by 10 years compared with Zhao et al. (2010).

- Lines 125-128. In the past (Zhao et al., 2010) 16 years of observations were used, so now you're using the same dataset, with 10 years of additional data? So you also compare the present results with those of Zhao et al. (2010)? If this is the case, be clear about this in objective nr. 1.

Reply: Thanks for these constructive comments.

Runoff data before 2005 used in the manuscript are the same datasets, rainfall data before 2005 used in the manuscript are the mean values of two datasets (one of them is the same as Zhao et al. (2010)). Runoff and rainfall data after 2005 used in the manuscript are not the same as Zhao et al. (2010). PET data were obtained from the SILO Data. Applying the data used in the manuscript to the analysis in Zhao et al. (2010), the results of three methods are 31.4%, 84.7%, and 53.7%, respectively. They are close to

the original results (27%, 71%, 57%) in Zhao et al. (2010) The data used in the manuscript are available.

- Line 137; dominant soil texture?

Reply: Thanks for your helpful suggestions. "soil types" will be replaced by "soil texture".

- Line 138: average slope? For both sites?

Reply: Thanks for these constructive comments.

The average slope is unknown, and only "The topography is rolling or undulating with mostly gentle slopes in Kileys Run" and "Topology of these two catchments are similar" can be found in the cited references.

- Lines 138-139; Sentence may be removed to next paragraph, it feels misleading because of the information which is "missing" in line 139, but actually described from line 143 on.

Reply: Thanks for your suggestions. Changes will be made as suggested. The sentence in Lines 139-139 will be removed to next paragraph in the revised manuscript.

- Lines 139-147; what is the variation in monthly rainfall? Seasonal? What Köppen climate?

Reply: Thanks for these constructive comments.

The variation in monthly rainfall can be seen in Figure R2. Seasonal changes in monthly rainfall can be seen in Figure R3. The monthly rainfall decreased great during the period of 2001-2009 and increased after 2010, but is still less than the monthly rainfall before 2001. There is more precipitation in winter (June, July and August), but the difference amongst rainfall of four seasons is small. The climate type in Kileys Run and Red Hill catchment is Cfb (temperate maritime climate) (Peel et al., 2007).

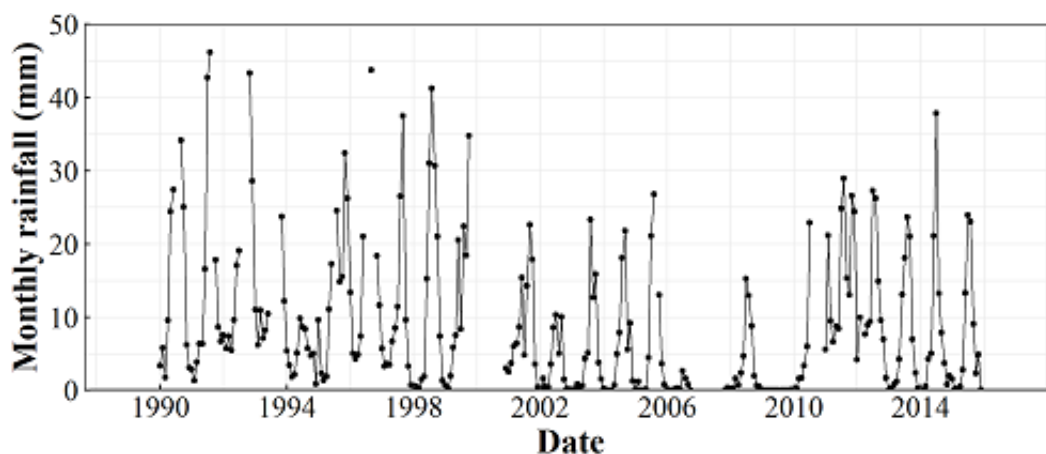


Figure R2 The variation in monthly rainfall of the Kileys Run catchment (control catchment), New South Wales, Australia, during the periods of 1990–2015.

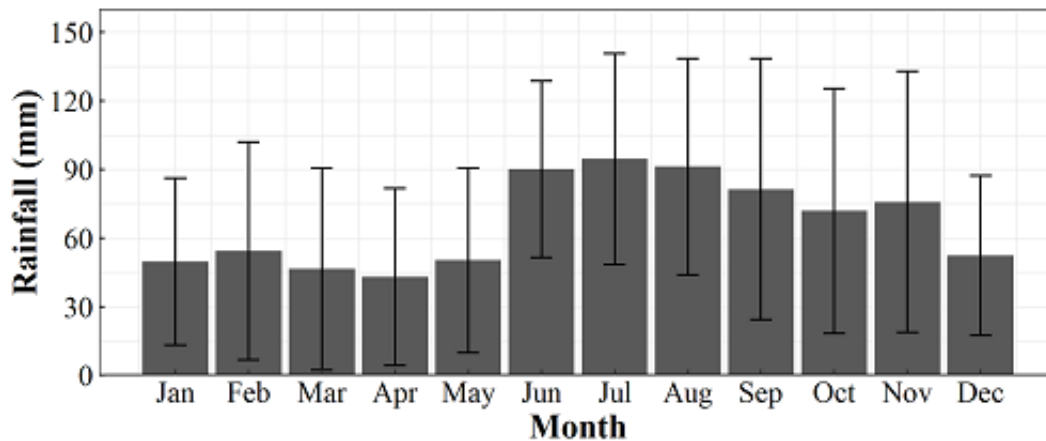


Figure R3 Seasonal changes in monthly rainfall of the Kileys Run catchment (control catchment), New South Wales, Australia, during the periods of 1990–2015. The bar represents the average rainfall of each month, the error bar represents the standard deviation of rainfall of each month.

- Line 147-148; “potential evapotranspiration records.....” yes, what? Ranges, values? Differences in AET between control and treated catchment?

Reply: Thanks for these constructive comments.

Monthly potential evapotranspiration (PET) records used in the manuscript is from 1990 to 2015, the change of annual PET can be seen in Figure 8 (b), and the mean annual PET is 1219 mm. In this manuscript, control catchment and treated catchment use the same PET dataset. The difference between the mean annual AET of control catchment ($817-161=656$ mm) and treated catchment ($817-75=742$ mm) are 86 mm base on the water balance method.

- Lines 149-151; I am curious to understand why you do show the prolonged drought for Kileys Run, but not for Red Hill;

Reply: Thanks for bringing this to our attention. Detailed analysis of the reasons can be seen in Comment 1. There is a flaw in the original hypothesis and it is revised in the separated document as attached.

- Line 157; I don’t want to be a nit-pickier, but you say short length of the observed data record. I am not aware of many locations where they have a data record for this very nice (long) period of 25 years.

Reply: Thanks for these constructive comments.

It needs long time to allow runoff generation to change from one equilibrium state to a new equilibrium state after a vegetation changes, especially for afforestation. A data record for a period of 25 years used in this manuscript is to test whether the difference amongst three method is caused by the shorter length of the observed data used in Zhao et al. (2010) (16 years of observations may not make the runoff reach a new equilibrium state).

- Line 248; you do introduce the parameters *SC* and *C* before giving any of the related equations.

Reply: Thanks for your helpful suggestions. The parameters *SC* and *C* will be introduced

carefully before giving any of the related equations in the revised manuscript.

- Line 302-307 and Table 1; beta what? Add name of method;

Reply: β represents the rate of changes of annual rainfall or runoff. It was obtained by Sen's method (Sen, 1968) ("trend" package in R software). The meaning of the parameter β will be introduced carefully and the name of the method to obtain β will be added in the revised manuscript.

- Lines 308-310; unclear;

Reply: Figure 4 (a) shows the relationship between monthly runoff of control catchment and monthly runoff of treated catchment during the calibration period. Figure 4 (b) shows the relationship between monthly runoff and monthly rainfall of treated catchment during the calibration period (i.e. 1990–1996). It will be explained clearly in the revised manuscript.

- Figure 4. A. The left figure is Kileys Run, but in the caption you mention Red Hill first, change either the caption or the figure order. B. The x- and y-axis do have different ranges, this makes the graphs difficult to compare and to understand the meaning of the results.

Reply: Thanks for your helpful suggestions. Figure 4 will be replaced by Figure R4 in revised manuscript as follows:

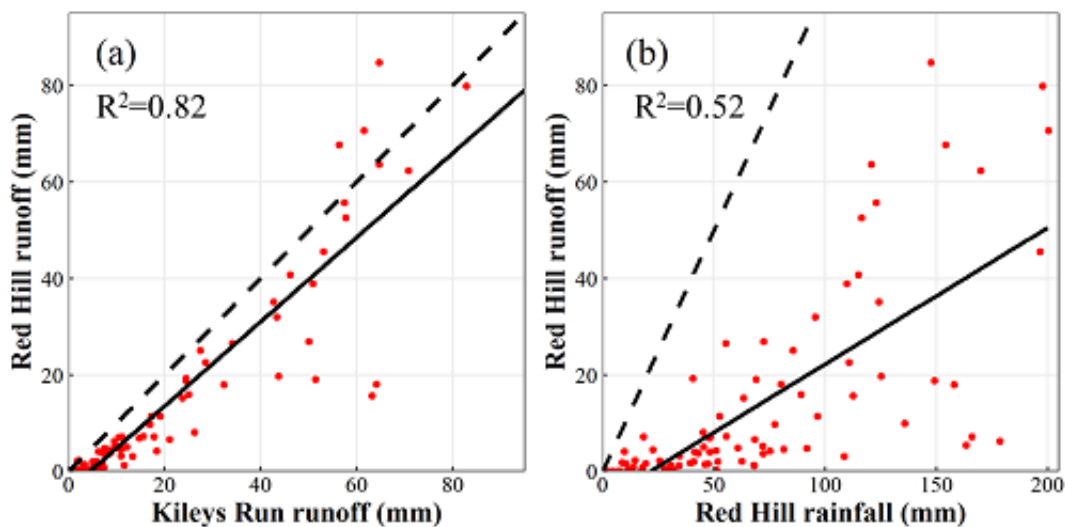


Figure R4. (a) Monthly runoff at control (Kileys Run) vs. treated (Red Hill) catchments in New South Wales, Australia, during the calibration period, and (b) Monthly rainfall vs. runoff of the treated catchment during the calibration period. Dashed line is the 1:1 line.

A. The title of Figure 4 has been changed to that of Figure R4.

B. The runoff-runoff relationship for the two paired catchments in Figure 4 (a) is used in the paired catchment method, and the rainfall-runoff relationship of the treated catchment in Figure 4 (b) is used in the time-trend analysis method.

- Lines 310-314; add name of method (so the reader can go back to paragraph 3..... to understand the applied method);

Reply: Thanks for your helpful suggestions. Modified text in the revised manuscript as

follows:

The R^2 values of the monthly runoff-runoff relationship in the paired catchment method and the monthly rainfall-runoff relationship in the time-trend analysis method were 0.82 and 0.52, respectively. The linear relationships were $Q_{t1}=0.873.9*Q_{c1}-3.9$ and $Q_{t1}=0.28*P_{t1}-6.0$, respectively.

- Line 312; it's conflictingly that you express Q_{RH} first as Q_{KR} and after expressing Q_{RH} at as P_{RH} , as a reader I cannot compare Q_{KR} as P to see the differences in slope or offset based on P . Can you express Q_{kr} as P as well?

Reply: Thanks for your helpful suggestions. Revised Eq. (6) and Eq. (7) in section 3.1.2 as follows:

$$Q_{t1} = aP_{t1} + b \quad (6)$$

$$Q'_{t2} = aP_{t2} + b \quad (7)$$

" Q_{RH} " will be replaced by " Q_{t1} ", " Q_{KR} " will be replaced by " Q_{c1} " and " P_{RH} " will be replaced by " P_{t1} ". It is consistent with the section 3.1.1 and 3.1.2.

- Lines 355-356; you made your point about the differences between the periods, but you may consider move this sentence to the discussion and use a physical understanding and references to explain the cause of drought;

Reply: Thanks for your helpful suggestions. This sentence will be moved to the discussion, and the cause of drought has been explained according to a physical understanding and references in the manuscript (section 5.2).

- Figure 6; you may consider add the daily flow duration curve for the entire measurement period (1990-2015) to indicate the differences;

Reply: Thanks for your helpful suggestions. The daily flow duration curve including the entire measurement period (1990-2015) can be seen in Figure R5.

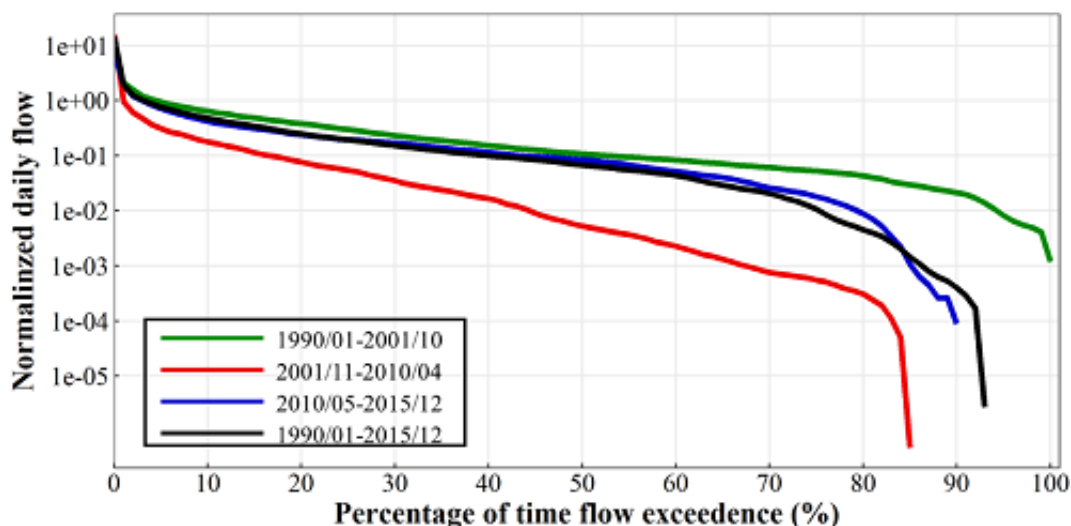


Figure R5. Daily flow duration curves of the Kileys Run catchment (i.e., control catchment), New South Wales, Australia, over four different periods (see legend).

The FDC of the entire measurement period (1990-2015) is close to the FDC of the third

period (2010-2015). There is 6% no-flow days during the whole period. In the first period (pre-drought), the second period (after drought) and the whole period (including the whole drought period), high flows have a highly consistent change, but the difference amongst low flows is significant. It indicates that the impact of prolonged drought on the low flow is more serious than that of the high flow. When the rainfall increases, the high flow may recover quickly, but the low flow may recover slowly.

- Line 373; which method? Refer to paragraph....

Reply: Double mass curves, flow duration curves and rainfall-runoff linear regression curves were employed to detect changes in the rainfall-runoff relationship (Page 12, Lines 233-234; refer to section 4.2.1).

- Figure 7; The x-axis of the graphs could be better aligned;

Reply: Thanks for your helpful suggestions. Figure 7 will be replaced by Figure R6.

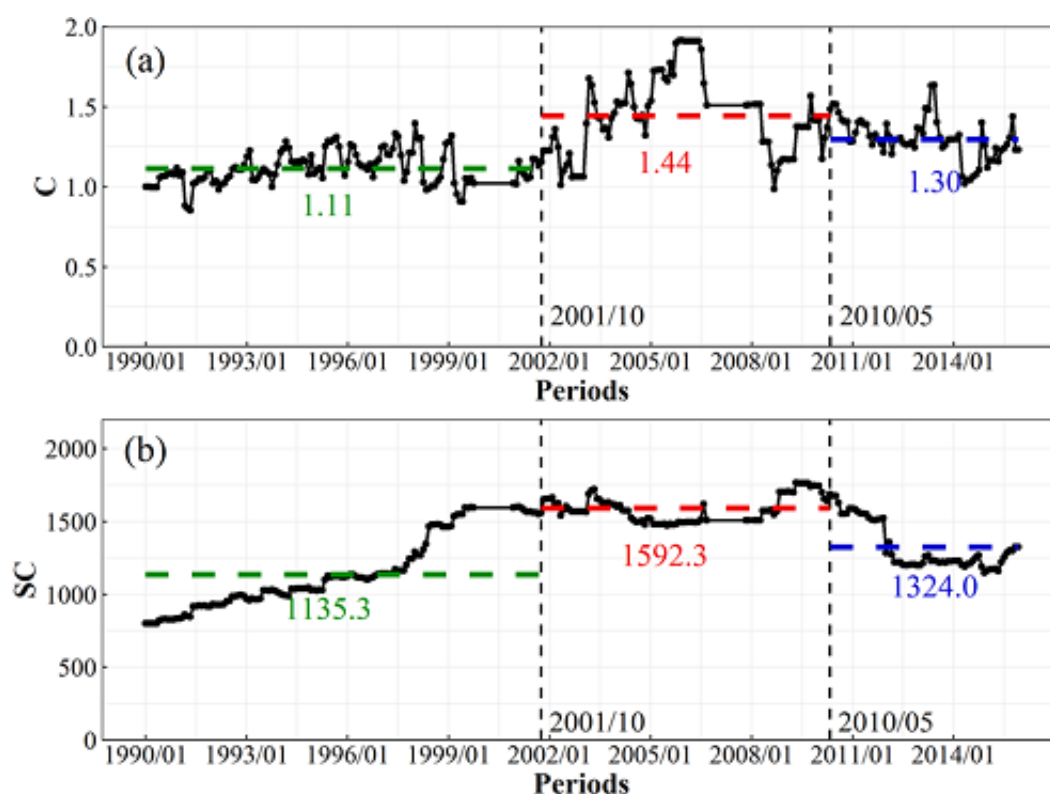


Figure R6. Estimated monthly values of parameters (a) C and (b) SC used in the two-parameter monthly water balance model for the Kileys Run catchment (control catchment), New South Wales, Australia, during the period of 1990–2015.

- Line 385; correlated with catchment runoff; you may consider adding the R and p -value;

Reply: Thanks for your helpful suggestions. The R (based on Kendall's tau) between monthly runoff and SC is 0.25 (p -value < 0.001).

- Line 404-405; "by using the method mentioned in section 3.3" why not mention the name of the method and refer to the section?

Reply: Thanks for your helpful suggestions. Data revision method will be not used in the

revised manuscript anymore. The revised methods can be seen in section 2 in the separated document as attached.

- Figure 9; no data for 1999, 2000, 2006, and 2007? Not mentioned in the text/method section? Or did I misread something?

Reply: Most of the data are missing in 1999, 2000, 2006 and 2007.

- Figure 10; does it shows median values for a period or means, or?

Reply: Yes, it shows mean values for a period.

References

Dey, P., and Mishra, A.: Separating the impacts of climate change and human activities on streamflow: A review of methodologies and critical assumptions, *J. Hydrol.*, 548, <https://doi.org/10.1016/j.jhydrol.2017.03.014>, 2017.

Padrón, R., Gudmundsson, L., Greve, P., and Seneviratne, S.: Large-Scale Controls of the Surface Water Balance Over Land—Insights From a Systematic Review and Meta-Analysis, *Water Resour. Res.*, 53, <https://doi.org/10.1002/2017wr021215>, 2017.

Peel, M. C., Finlayson, B. L., and McMahon, T. A.: Updated world map of the Köppen-Geiger climate classification, *Hydrology & Earth System Sciences*, 11, 259-263, 2007.

Saft, M., Western, A., Zhang, L., Peel, M., and Potter, N.: The influence of multiyear drought on the annual rainfall-runoff relationship: An Australian perspective, *Water Resour. Res.*, 51, <https://doi.org/10.1002/2014WR015348>, 2015.

Sen, P.: Estimates of the Regression Coefficient Based on Kendall's Tau, *J. Am. Stat. Assoc.*, 63(324), <https://doi.org/10.1080/01621459.1968.10480934>, 1968.

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