Response to Reviewer #1

R1. The authors use three periods for each catchment, but only one of these is common, i.e. the first two periods overlap but are not coincident making their results hard to compare. There are four periods present: (i) 1990-96 pre-drought and untreated, (ii) 1997-2000 pre-drought and treated, (iii) 2001-09 in-drought and treated, and (iv) 2010-15 post-drought and treated. Table 2 and Figure 6 essentially compares pre-drought+untreated to post-drought+treated where all effects have been expressed. Do the traditional applications work consistently when comparing the pre- and in-drought conditions prior to significant changes in the post-drought rainfall-runoff relationship? It would be good to see the different methods applied to matching temporal periods of rainfall and flow data, and the gradual divergence of the attribution of vegetation and climatic effects as more effects are imposed on the paired catchments.

Response: Thanks very much for your great efforts to assess our manuscript. We have studied your comments carefully and have made corrections/revisions as suggested. We have detailed how these comments (in black) are raised and our responses (in deep sky blue).

(1) Thanks for your constructive comment. We agree that the treated catchment (afforestation) experienced four periods, (i) 1990–1996 pre-drought and untreated, (ii) 1997–2001 pre-drought and treated, (iii) 2002–2009 in-drought and treated, and (iv) 2010–2015 post-drought and treated. In the (i) period, runoff of the threated catchment has not been significantly affected, it can be considered as the calibration period for evaluating the impact of vegetation change on runoff. In the (ii) period, the treated catchment was affected by both vegetation change and climate variability. In the (iii) and (iv) periods, the treated catchment was affected by multiyear drought, vegetation change and climate variability, because the rainfall-runoff relationship after multiyear drought still cannot recover to that before multiyear drought (Fig. 4) and may persist such state for a long time (Peterson et al., 2021). When separating impacts of vegetation change and multiyear drought on runoff, the data of the control and treated catchments need to be used at the same period, that is to say, the same period needed to be applied to these two catchments. After comprehensively considering the principles of the three methods, we combined the (ii), (iii) and (iv) periods of the treated catchment into one period as the prediction period. That is to say, Table 2 and Fig. 6 essentially compared untreated (1990–1996) to treated (1997–2015). Runoff difference between the untreated and treated periods in the treated catchment was caused by vegetation change, climate variability and multiyear drought, and runoff difference in the control catchment was caused by climate variability and multiyear drought. The traditional applications of the PCM, TTM and SBM did not consider runoff changes caused by non-stationary rainfall-runoff relationship induced by multiyear drought, so the TTM and SBM overestimated the impact of vegetation change on runoff. In the new framework, the impact of multiyear drought on runoff can be independently quantified by combining the TTM and the data of the control catchment.

(2) We compared estimated changes between pre-drought+untreated (1990-1996) and pre-drought+treated (1997–2001) as well as between pre-drought+untreated (1990–1996) and in- and post-drought+treated (2002–2015). The contribution of vegetation change to the total runoff changes of the Red Hill catchment can be seen in Fig. R1. Impacts of afforestation on runoff were 34.3%, 65.9% and 41.5% of the total runoff changes during the period of 1997–2001 by the PCM, TTM and SBM, respectively. Impacts of afforestation on runoff were 32.4%, 100.8% and 68.4% of the total runoff changes during the period of 2002–2015. It can be seen that results of the TTM and

SBM during the period of 2002–2015 were significantly higher than those during the period of 1997–2001, while the results of PCM were close. Because multiyear drought happened in 2002–2009 and caused persistent effects in 2010–2015 had a great impact on the rainfall-runoff relationship of the Red Hill catchment, which made the TTM and SBM overestimated the impact of vegetation change on runoff more seriously. That is to say, errors of the gradual attribution of vegetation change to runoff total changes estimated by the TTM and SBM will become larger and larger as more effects are imposed on the paired catchments.

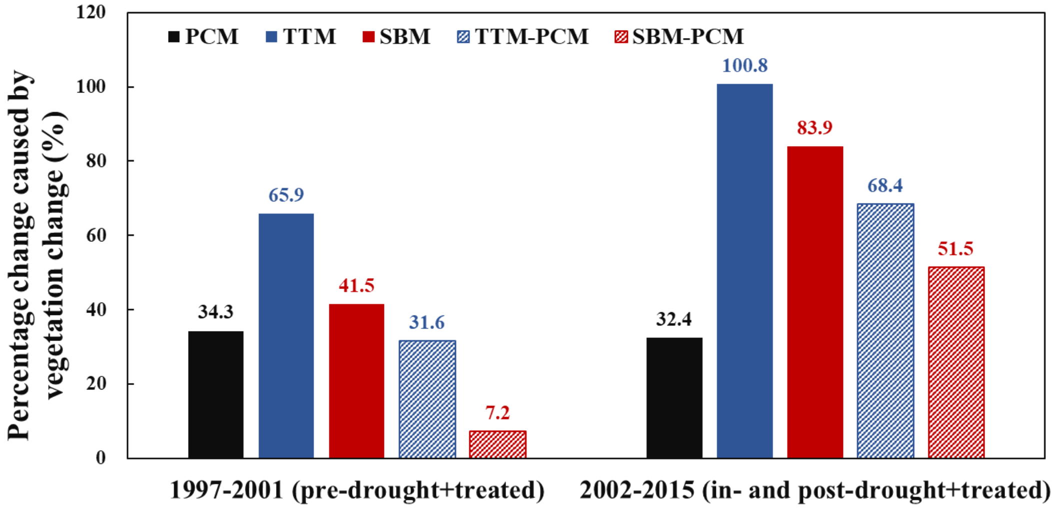

Figure R1: The contribution of vegetation changes to the total runoff changes of the Red Hill catchment estimated traditionally using all three methods during the pre-drought+treated period (1997–2001) and during the in- and post-drought+treated period (2002–2015).

R2. It is not clear what the x-axis units are in Figure 4e. The caption states “cumulative monthly rainfall” while the x-axis is labelled “N” and runs from zero to 50,000. It cannot be days passed as this implies over 100-years, or months, or even rainfall as this would mean there is more than double the net rainfall in the adjacent catchment. Please clarify the units and label.

Response: We apologize for this mistake. The x-axis of Fig. 4 (e) should be number of cumulative months. The total number of months of study period is 321 (12×26=321). Mistake in x-axis of Fig. 4 (e) is corrected and shown as follows.

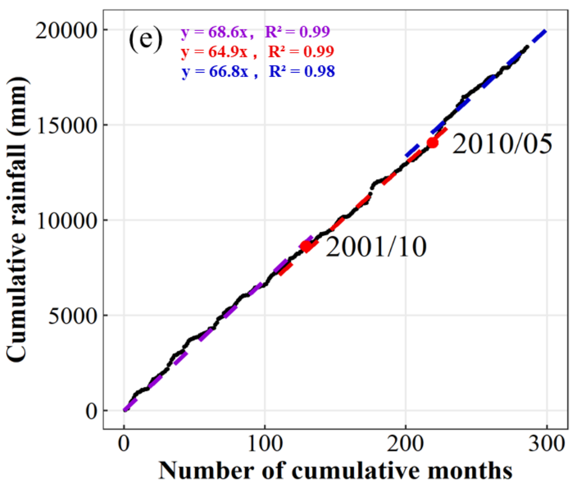

Figure 4: (e) Cumulative monthly rainfall of paired catchments during the period of 1990–2015. The dashed lines represent the linear regression lines between cumulative rainfall and number of cumulative months during three different periods (January 1990 to October 2001 (purple), November 2001 to May 2010 (red), and June 2010 to December 2015 (blue)).

Cumulative monthly rainfall figure can identify the prolonged low or high rainfall periods visually. Essentially, Fig. 4 (e) shows same information as Fig. 2. Moreover, information about prolonged drought period in Fig. 2 is more obvious and clearer using the anomaly. Therefore, we would like to delete redundant Fig. 4 (e) in the revised manuscript (see Line 275).

R3. Both the panels in Figure 5 appear to be the same – the FDC for Kileys Run is very different in the previous version.

Response: We apologize for this mistake. The FDC of the Kileys Run catchment in previous version is right. Figure 5 has been modified in the revised manuscript (see Line 305).

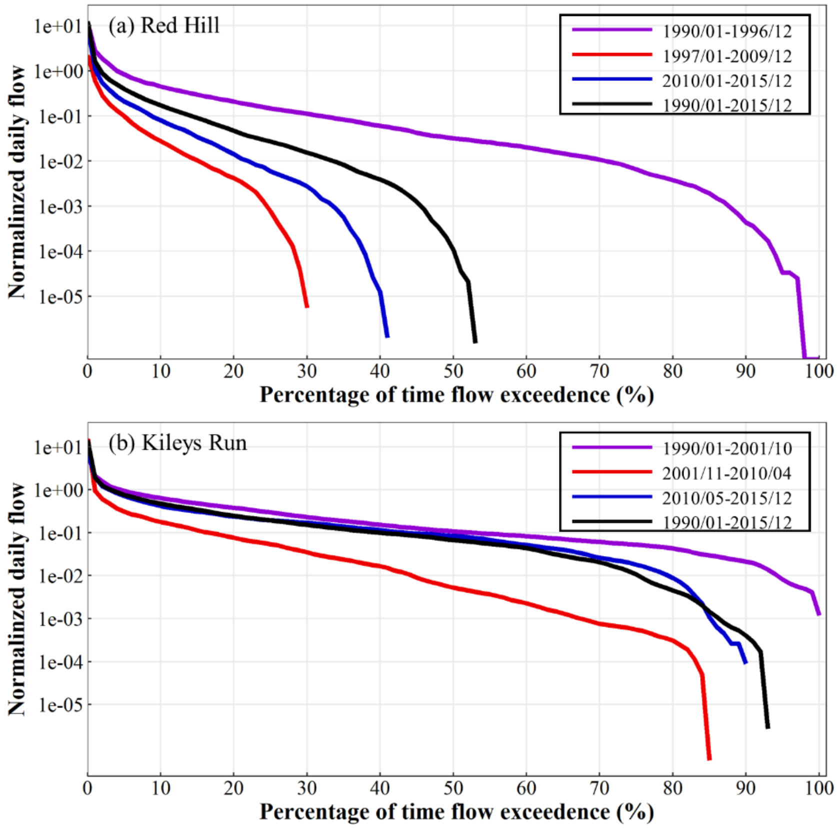

Figure 5: Daily flow duration curves of (a) the Red Hill catchment (treated catchment) and (b) the Kileys Run catchment

R4. Why do we get to Page 16 Figure 7 before seeing that four individual years of rainfall data (1999, 2000, 2006, 2007) appear to be missing? Are these data interpolated from SILO? Are some other data used in the climate analysis, or runoff analysis? Does their presence or otherwise influence the detection of change points or the regressions and relative contributions to runoff variation?

Response: Thanks for your constructive comment. The rainfall data used in this study was observed on site rather than interpolated gridded SILO data. There are missing values in both rainfall and runoff data. Both runoff and rainfall observations are missing from November 1999 to November 2000 and from October 2006 to October 2007. In order to minimize the influences of missing values on the annual total values, annual total is regarded as missing value if more than one month is missing. Thus, there are four missing data points in annual time series of rainfall.

We believe that the missing data has little impact on the final results. Two periods with missing data are just at the beginning and end of multiyear drought. Missing rainfall values should not differ significantly from the annual rainfall values during multiyear drought period. The overall trend or segmented trend during drought will not change much due to the lack of rainfall data. It is also true for annual runoff. In addition, the change point of annual runoff calculated with data including missing values was consistent with that by Zhao et al. (2010), both appeared in 1996. Based on data including missing data, estimated afforestation impacts were 31.4%, 84.7% and 64.9% of the total runoff changes during the period of 1990–2005 by the PCM, TTM and SBM, respectively. Results of Zhao et al. (2010) were 27.0%, 71.0% and 57% by the PCM, TTM and SBM, respectively. They were very close. Furthermore, same analysis was conducted based on the gridded rainfall data from SILO. Estimated afforestation impacts were 32.8%, 93.5% and 73.0% of the total runoff changes during the period of 1990–2015 by the PCM, TTM and SBM, respectively. The results were very close to results using in-situ observed rainfall as presented in the manuscript. Therefore, we believe processing of missing data has little influences on the estimated changes.

R5. The authors over-use the word "proved" in this paper, as they have "shown" by way of a single case study that rainfall-runoff is non-stationary but it does not invalidate PCM, for example. And in answer to the article's title, no I do not believe that the PCM is invalidated, and the method presented can account for such changes, assuming linearity of response between control and treated catchments.

Response: We appreciate this insightful comment. We agree with reviewer's arguments. We replaced the word "proved" with "demonstrated" or "shown" where they were suitable in the revised manuscript.

Relevant text reads (Line 9): "Multiyear drought has been demonstrated to cause non-stationary rainfall-runoff relationship."

(Line 15): "In addition to afforestation, the Red Hill paired experimental catchments have experienced a 10-year drought (2000–2009) and have been demonstrated to lead to non-stationary rainfall-runoff relationships of paired catchments."

(Line 26): "This study not only demonstrated that multiyear drought can induce non-stationary rainfall-runoff relationship using field observations,…"

(Line 28): "More importantly, it is shown that non-stationarity induced by multiyear drought does not invalidate the PCM, and PCM is still the most reliable method even the control catchment experienced climate-induced shift in the rainfall-runoff relationship."

(Line 77): "If this hypothesis mentioned above is demonstrated to be correct,…"

(Line 302): "In summary, the shape and percentage of the zero flows of FDCs in Fig. 5 further demonstrated that the relationship between rainfall and runoff of the two catchments changed significantly over the three periods,…"

(Line 403): "It ignored the impact of multiyear drought on runoff, which has been demonstrated to cause non-stationary changes. ”

(Line 479): "…, which is close to 100% and shows that the assumption is basically reasonable and valid."

(Line 557): "We demonstrated that the PCM was still a valid and fundamental method estimating the impact of vegetation change on runoff even the control catchment experienced hydroclimatic non-stationarity in the rainfall-runoff relationship under changing environments."

References:

Peterson, T. J., Saft, M., Peel, M. C., and John, A.: Watersheds may not recover from drought, Science, 372, 745-749, https//doi.org/10.1126/science.abd5085, 2021.

Zhao, F., Zhang, L., Xu, Z., and Scott, D. F.: Evaluation of methods for estimating the effects of vegetation change and climate variability on streamflow, Water Resour. Res., 46, https//doi.org/10.1029/2009WR007702, 2010.

Response to Reviewer #2

Response: Thanks very much for your great efforts to assess our manuscript. We have made technical corrections in the revised manuscript (see Table 2).