The original manuscript is improved as follows:

1. Main assumptions

1) The runoff reduction ($\overline{\Delta \boldsymbol{Q}_{t}^{total}}$) in the treated catchment is mainly caused by climate variability ($\overline{\Delta \boldsymbol{Q}_{t}^{clim}}$), changes in rainfall-runoff relationship induced by vegetation change ($\overline{\Delta \boldsymbol{Q}_{t}^{rrc-veg}}$) and prolonged drought ($\overline{\Delta \boldsymbol{Q}_{t}^{rrc-PD}}$). The runoff reduction in the control catchment is mainly caused by climate variability ($\overline{\Delta \boldsymbol{Q}_{c}^{clim}}$) and prolonged drought ($\overline{\Delta \boldsymbol{Q}_{c}^{rrc-PD}}$).

2) $\overline{\Delta \boldsymbol{Q}_{t}^{rrc-veg}}$, $\overline{\Delta \boldsymbol{Q}_{t}^{clim}}$ and $\overline{\Delta \boldsymbol{Q}_{t}^{rrc-PD}}$ are independent, that is, $\overline{\Delta \boldsymbol{Q}_{t}^{rrc-veg}} + \overline{\Delta \boldsymbol{Q}_{t}^{clim}} + \overline{\Delta \boldsymbol{Q}_{t}^{rrc-PD}} \approx \overline{\Delta \boldsymbol{Q}_{t}^{total}}$.

3) Climate variability does not change the rainfall-runoff relationship. That is to say, climate variability does not alter runoff ratio (or slope between accumulated annual rainfall and accumulated annual runoff) and runoff sensitivity to rainfall (P) and potential evapotranspiration (PET). It means time-trend and sensitivity-based methods still applicable.

4) Both prolonged drought and vegetation change can lead to change in rainfall-runoff relationship.

5) The percentage of runoff reduction caused by prolonged drought (P^{PD}, ratio between runoff reduction caused by prolonged drought and the annual mean runoff during the calibration period) is the same in control and treated catchments. That is to say, impacts of prolonged drought on rainfall-runoff relationship is independent of catchment properties.

2. Calculation process

1) Total runoff changes in the treated catchment: $\overline{\Delta \boldsymbol{Q}_{t}^{total}}$

Total runoff changes are the difference between the observed mean annual runoff during the prediction period and the calibration period.

$$\overline{\Delta Q_{t}^{total}} = \overline{Q_{t2}^{obs}} - \overline{Q_{t1}^{obs}} \quad (2.1)$$

where subscript 1 denotes the calibration period; subscript 2 denotes the prediction period (suffered from prolonged drought and vegetation change); subscripts t and c represent treated and control catchments, respectively; superscript *obs* denotes observed data times series; $\overline{Q_{t2}^{obs}}$ represents the observed mean annual runoff during the prediction period; $\overline{Q_{t1}^{obs}}$ represents the observed mean annual runoff during the calibration period.

2) Runoff changes caused by vegetation change in the treated catchment: $\overline{\Delta \boldsymbol{Q}_{\boldsymbol{t}}^{\boldsymbol{rrc-veg}}}$

It can be obtained by **paired catchment method** because the only difference between control and treated catchments is the vegetation change. Paired catchment method eliminates the effects of both prolonged drought and climate variability on runoff of the treated catchment by using control catchment observations.

By applying the paired catchment method in a traditional way as follows, $\overline{\Delta \boldsymbol{Q}_{\boldsymbol{t}}^{\boldsymbol{rrc-veg}}}$ can be obtained.

Firstly, it is assumed that runoff of the treated catchment is highly correlated with the runoff of the control catchment during the calibration period as expressed by eq. (2.2):

$$Q_{t1}^{obs} = a_1 Q_{c1}^{obs} + b_1 \tag{2.2}$$

where Q_{t1}^{obs} is the observed monthly runoff of the treated catchment in the calibration period, while Q_{c1}^{obs} is the observed monthly runoff of the control catchment in the calibration period; a_1 and b_1 are regression coefficients for the calibration period.

Secondly, it is assumed that the rainfall-runoff relationship shown in eq. (2.2) does not change during the prediction period and it can be used to remove the effect of climate variability and prolonged drought on runoff in treated catchment. This is achieved by eq. (2.3) and eq. (2.4):

$$Q_{t2}^{sim} = a_1 Q_{c2}^{obs} + b_1 \tag{2.3}$$

$$\overline{\Delta Q_{t}^{rrc-veg}} = \overline{Q_{t2}^{obs}} - \overline{Q_{t2}^{sim}} \tag{2.4}$$

where Q_{t2}^{sim} is the simulated monthly runoff of the treated catchment during the prediction period using the paired catchment method; Q_{c2}^{obs} is the observed monthly runoff of the control catchment during the prediction period; and $\overline{\Delta \mathrm{Q}_{t}^{rrc-veg}}$ is the estimated impact of vegetation change on runoff using the paired catchment method.

3) Runoff changes caused by prolonged drought: $\overline{\Delta \boldsymbol{Q}_{\boldsymbol{c}}^{\boldsymbol{rrc-PD}}}$、 $\overline{\Delta \boldsymbol{Q}_{\boldsymbol{t}}^{\boldsymbol{rrc-PD}}}$

It can be obtained by applying **time-trend analysis method** to observed runoff of the **control catchment**.

Changes in runoff of the control catchment is induced by climate variability and prolonged drought. The rainfall-runoff relationship which is not affected by prolonged drought can be obtained by eq. (2.5) in the control catchment during calibration period.

$$Q_{c1}^{obs} = c_1 P_{c1}^{obs} + d_1 \qquad (2.5)$$

where P_{c1}^{obs} is the observed monthly precipitation of the control catchment in the calibration period; c_1 and d_1 are regression coefficients for the calibration period.

The simulated runoff not affected by prolonged drought during the prediction period can be obtained by eq. (2.6), while the runoff change caused by prolonged drought can be obtained by eq. (2.7).

$$Q_{c2}^{sim} = c_1 P_{c2}^{obs} + d_1 \qquad (2.6)$$

$$\overline{\Delta Q_c^{rrc-PD}} = \overline{Q_{c2}^{obs}} - \overline{Q_{c2}^{sim}} \qquad (2.7)$$

where Q_{c2}^{sim} is the simulated monthly runoff not affected by prolonged drought in the control catchment during the prediction period; P_{c2}^{obs} is the observed monthly precipitation of the control catchment in the prediction period; $\overline{Q_{c2}^{obs}}$ represents the observed mean annual runoff during prediction period; and $\overline{\Delta Q_c^{rrc-PD}}$ is the estimated impact of prolonged drought on runoff in the control catchment.

The percentage of runoff reduction (P^{PD}) caused by prolonged drought in the control catchment:

$$P^{PD} = |\overline{\Delta Q_c^{rrc-PD}} / \overline{Q_{c1}^{obs}}| \qquad (2.8)$$

where $\overline{Q_{c1}^{obs}}$ represents the observed mean annual runoff during the calibration period.

For the treated catchment, prolonged-drought induced changes relative to the calibration period is assumed the same as that of the control catchment.

Runoff reduction caused by prolonged drought in the treated catchment ($\overline{\Delta Q_t^{rrc-PD}}$):

$$\overline{\Delta Q_t^{rrc-PD}} = P^{PD} \times \overline{Q_{t1}} \qquad (2.9)$$

4) Runoff changes caused by climate variability in treated catchment: $\overline{\Delta Q_t^{clim}}$

It can be obtained by **sensitivity-based method**, $\overline{\Delta Q_t^{clim}}$ is mainly caused by changes of P and PET.

$$\overline{\Delta Q_t^{clim}} = \beta \Delta P + \gamma \Delta PET \qquad (2.10)$$

$$\beta = \frac{1 + 2x + 3wx^2}{(1 + x + wx^2)^2} \qquad (2.11)$$

$$\gamma = -\frac{1+2wx}{(1+x+wx^2)^2} \quad (2.12)$$

where ΔP is the difference of P during prediction and calibration periods; ΔPET is the difference of PET during prediction and calibration periods.

5) The contribution percentage of vegetation change, prolonged drought and climate variability to runoff reduction in the treated catchment: $\boldsymbol{p_t^{rrc-veg}}$, $\boldsymbol{p_t^{rrc-PD}}$, $\boldsymbol{p_t^{clim}}$

$$p_t^{rrc-veg} = \overline{\Delta Q_t^{rrc-veg}} / \overline{\Delta Q_t^{total}} \quad (2.13)$$

$$p_t^{rrc-PD} = \overline{\Delta Q_t^{rrc-PD}} / \overline{\Delta Q_t^{total}} \quad (2.14)$$

$$p_t^{clim} = \overline{\Delta Q_t^{clim}} / \overline{\Delta Q_t^{total}} \quad (2.15)$$

3. Results

1) $\overline{Q_{t1}^{obs}} =$ 169.4 mm; $\overline{Q_{t2}^{obs}} =$ 31.3 mm; $\overline{\Delta \boldsymbol{Q_t^{total}}} =$ **−138.1 mm;**

2) $\overline{Q_{t2}^{sim}} =$ 76.6 mm; $\overline{\Delta \boldsymbol{Q_t^{rrc-veg}}} =$ **−45.3 mm**;

3) $\overline{Q_{c1}^{obs}} =$ 247.4 mm; $\overline{Q_{c2}^{obs}} =$ 121.1 mm; $\overline{Q_{c2}^{sim}} =$ 231.3 mm; $\overline{\Delta Q_c^{rrc-PD}} = -110.2$ mm;

$P^{PD} =$ 45 %; $\overline{\Delta \boldsymbol{Q_t^{rrc-PD}}} =$ **−75.5 mm**;

4) $\beta =$ 0.39; $\gamma = -0.16$; $\Delta P = -56.0$ mm; $\Delta PET =$ 70.3 mm; $\overline{\Delta \boldsymbol{Q_t^{clim}}} =$ **−33.0 mm**;

5) $p_t^{rrc-veg} =$ 32.8 %; $p_t^{rrc-PD} =$ 54.7 %; $p_t^{clim} =$ 23.9 %;

A. Traditional application

The bold red numbers represent results that can be calculated directly from the observation data. The bold black numbers are final results that are further calculated by the red bold numbers.

When the influence of prolonged drought on the rainfall-runoff relationship in control and treated catchments is not considered, the results of the time-trend analysis method and sensitivity-based method are considered to be caused by vegetation change. At this point, the result of the paired catchment method are underestimated (Table 3.1, Figure 3.1). The three methods used in this manuscript are the same as those used in Zhao et al. (2010). A 26-year record of observations (1990-2016, including the whole prolonged drought period) was used in this manuscript and a 15-year record of observations (1990-2005, the last five years were in prolonged drought period) was used in Zhao et al. (2010). Final results of traditional application in Table 3.1 were close to results (27%, 71%, 57%) in Zhao et al. (2010), which indicates that the prolonged drought rather than the length of the data record is likely the reason for this difference amongst three results.

Table 3.1 The contribution percentage of vegetation change to runoff reduction, estimated using three different method, without considering the impact of prolonged drought on rainfall-runoff relationship (A. Traditional application).

Traditional application	Paired catchment method	Time-trend analysis method	Sensitivity-based method
$p_t^{rrc-veg}$	**32.8%**	**93.5%**	100% - 23.9% = **76.1%**
p_t^{clim}			**23.9%**

B. Current application

In traditional application, it indicates that the prolonged drought is likely to cause the great difference amongst the three results. In current application, the influence of prolonged drought on the rainfall-runoff relationship in the control catchments is considered (it has been proved in the manuscript), but the influence of prolonged drought on the rainfall-runoff relationship in the treated catchments is not considered, and it was thought that runoff changes in the treated catchment are induced by climate variability (it did not cause non-stationary rainfall-runoff relationship) and vegetation change (it caused non-stationary rainfall-runoff relationship). For the paired catchment method, it actually considered the influence of prolonged drought on the rainfall-runoff relationship because it used the runoff data of the control catchment, which is contrary to the previous assumption. On this basis, the further work is to eliminate the impact of prolonged drought on the rainfall-runoff relationship in the control catchment during the prediction period (eq. (16) and (17), Page 15, Lines 294-295), so that the result obtained by the paired catchment method (used the revised runoff data of the control catchment) is consistent with the previous assumptions. The final results 73.4% (paired-catchment method, based on the revised runoff data of the control catchment), 93.5% (time-trend analysis method), 76.1% (sensitivity-based method) are consistent based on the assumption that prolonged drought do not change the rainfall-runoff relationship of the treated catchment (Table 3.2, Figure 3.1). Actually, this three results are the contribution percentage of prolonged drought and vegetation change as a whole to the runoff reduction in the treated catchment if prolonged drought lead to the change of rainfall-runoff relationship.

Table 3.2 The contribution percentage of vegetation change to runoff reduction, estimated using three different method, without the impact of prolonged drought on rainfall-runoff relationship in the treated catchment (B. Current application).

Current application	Paired catchment method	Time-trend analysis method	Sensitivity-based method
$p_t^{rrc-veg}$	32.8% → **73.4%**	**93.5%**	100% - 23.9% = **76.1%**
p_t^{clim}			**23.9%**

C. Modified application

When the influence of prolonged drought on the rainfall-runoff relationship in control and treated catchments is considered. Runoff reduction calculate by paired catchment method is induced by vegetation change, runoff reduction calculate by time-trend analysis method is induced by vegetation change and prolonged drought and runoff reduction calculate by sensitivity-based method is induced by climate variability. $p_t^{rrc-veg}$ in B. Current application (73.4%, 93.5%, 76.1%) actually induced by prolonged drought and vegetation change. It needs to further separate the effects of prolonged drought and vegetation change on runoff. Based on the hypothesis in session 1 and the calculation process in session 2, the contribution percentage of vegetation change, prolonged drought and climate variability to runoff reduction in the treated catchment can be obtained (Table 3.3, Figure 3.1). Independent estimated of three terms: $p_t^{rrc-veg} + p_t^{rrc-PD} + p_t^{clim}$=32.8%+54.7%+23.9%=111.4%, it is close to 100% (It shows that the impacts of vegetation change, climate variability and prolonged drought have interaction, but is small). $p_t^{rrc-veg}$ calculated by the three methods still become consistent.

Table 3.3 The contribution percentage of vegetation change to runoff reduction, estimated using three different method, with the impact of prolonged drought on rainfall-runoff relationship in the control and treated catchments (C. Modified application).

Modified application	Paired catchment method	Time-trend analysis method	Sensitivity-based method
$p_t^{rrc-veg} + p_t^{rrc-PD}$	32.8%+54.7% = **87.5%**	**93.5%**	100%-23.9% = **76.1%**
$p_t^{rrc-veg}$	**32.8%**	93.5%-54.7%=**38.8%**	100%-23.9%-54.7% = **21.4%**
p_t^{clim}	100%-23.9%-54.7% = **21.4%**	100%-93.5% = **6.5%**	**23.9%**
p_t^{rrc-PD}	**54.7%** (time trend for control catchment)	**54.7%**	**54.7%**

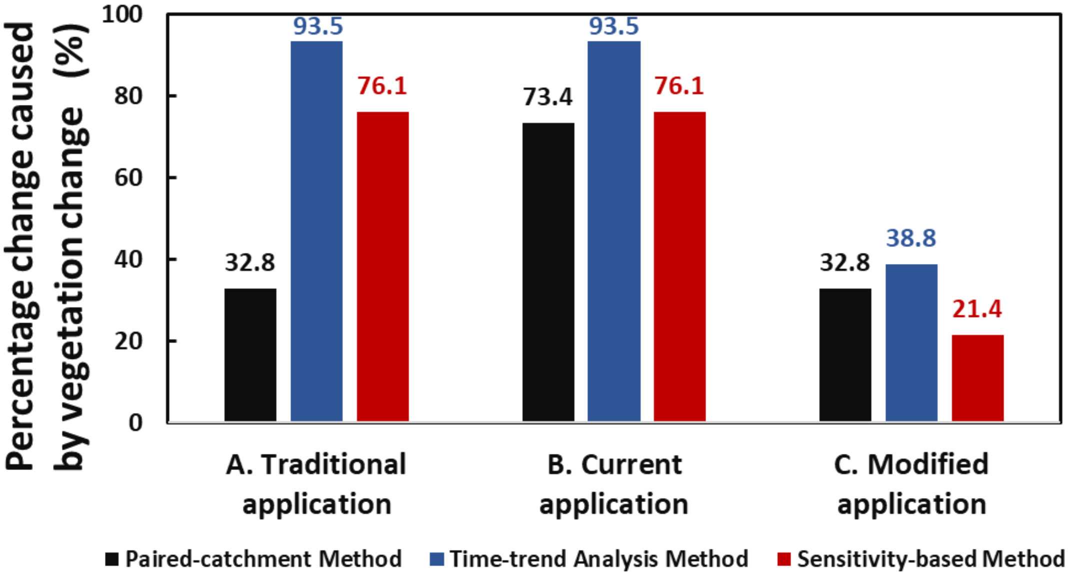

Figure 3.1 The contribution percentage of vegetation change to runoff reduction, estimated using three different method. (A. Traditional application, B. Current application, C. Modified application).