To Reviewer #2:

General Comments:

The authors analyze the drought impacts on the runoff ratio in China's Loess Plateau. The climate anomaly, relationships between precipitation-runoff, the implications for ecosystem, and the water resource management were discussed in the manuscript. The structure of the manuscript and the problems description are well organized, but there are several serious flaws in the data analysis, methods description, and interpretations of results. Thus, this version of the manuscript can not be accepted for publication in HESS.

[Response] We thank the reviewer for the comments. We have carefully considered all the reviewer's comments as followed. We believe the MS will be highly improved after the revision, with the flaws raised by the reviewer all being addressed.

[Reviewer #2 Comment 1] *First of all, the amount of the water consumption for the local communities (domestic and industrial usage) is vital for the runoff ratio in the study period, especially for during the drought. The authors should at least investigate the changes in the water supply for the local communities.*

[Response] We agree that the amount of the water consumption for the local communities is vital for the runoff ratio, especially for the drought period. For example, Bouwer et al. (2006) concluded that increasing water consumption for irrigation and hydropower caused runoff variability is three times higher than variation in runoff under climate change in which the area is densely populated and the main agricultural irrigation area in India . However, the water consumption for the local communities is not a major issue in our study area, which is composed by 13 loess hilly catchments.

With the Mu Us Desert in the northwest and the WeiHe Plain in the southeast, the catchments in our study lie in the most hilly part of the Loess Plateau. Water consumption for the local communities is for the residential area, locating mainly at the flat area at the outlet of the catchments (See the distribution of resident area in

Figure R2.1). Moreover, the population tend to move from the catchment area to the main big cities, locating in the mainstream of the River Basin in the WeiHe Plain (i.e. Baoji, Xi'an, 57.35%) because of the accelerated urbanization process in this area since the 1980s (Hu et al., 2001).

In line with our consideration, in the studies of runoff variability of the same catchment, water supply for the local communities was also not included as factor influencing runoff. Instead, anthropogenic factors of the change in runoff 13 catchments such as terrace building, soil conservation measures and so on (Wang et al., 2009; Shi et al., 2013; Chang et al., 2015). We will add the explanations in the revised MS.

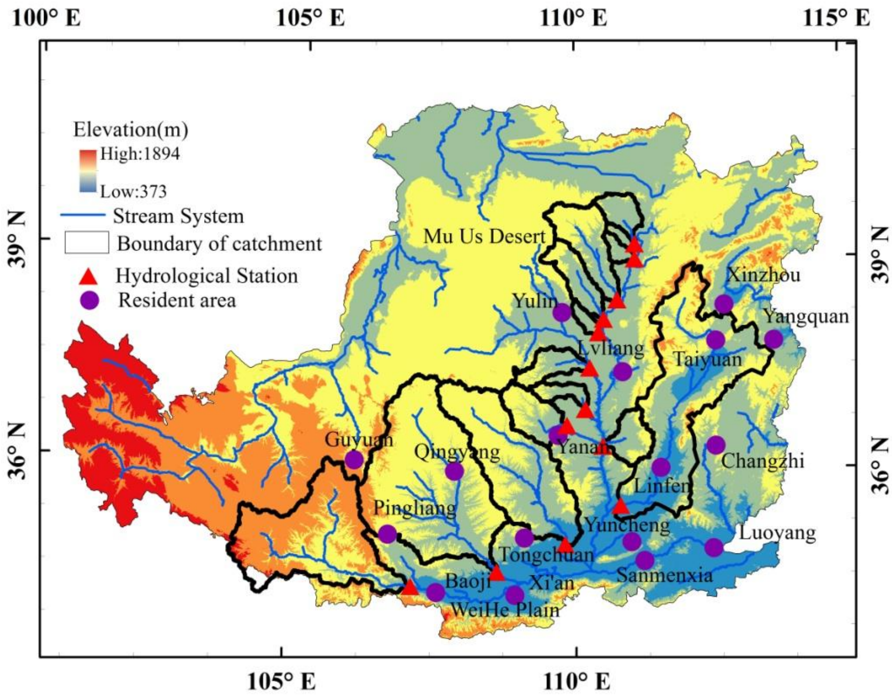

Figure R2.1. Study area

[Reviewer #2 Comment 2] *The precipitation-runoff relationships can be influenced by the land use, surface water diversion, irrigation scheme, groundwater abstraction, and the water storage in the (sub) catchment. These issues should be addressed for identifying the influence of drought on the water yield.*

[Response] We agree with the reviewer that the precipitation-runoff relationships can be influenced by factors other than climate conditions. We have carefully considered each possible factor in our study as followed.

The catchments lie in the most hilly part of the Loess Plateau, vegetation in the catchments is mostly rain-fed, thus irrigation scheme in the study area can be neglected (Feng et al., 2016). Loess thickness of the catchments area is more than 100m (Derbyshire et al., 1998), the groundwater is less impacted by the surface eco-hydrological process, thus groundwater recharge and groundwater discharge are not considered in the study area. Finally, the possible surface water diversion and water storage is in the residential area at the outlet these catchments (See detailed explanation in the response of the Reviewer#2 Comment 1), therefore is not included as the impact factor of the precipitation-runoff relationships.

However, soil conservation measures, including terraces construction and sediment-trap dams building, have been implemented in the Loess Plateau since the 1950s (Wang et al., 2016). We will add the description on the influence of these human-stimulated measurements to precipitation-runoff relationships in the revised MS. The partial correlation method will be used to isolate the impact of human-stimulated measurements from climatic factor.

For the entire period of 1982–1999, the runoff had a decreasing trend (Figure R2.2).Terrace construction played an important role in the runoff ratio reduction from 1980s to 1990s (p=0.048, Figure R2.3). Other anthropogenic factors including dam construction, tree and pasture plantation had not caused the change in runoff ratio in this period. Terra construction contributed 25% of the runoff ratio reduction in 1990s, so the drought is the major factor of the runoff reduction in the study area. We will add the analysis in the revised MS.

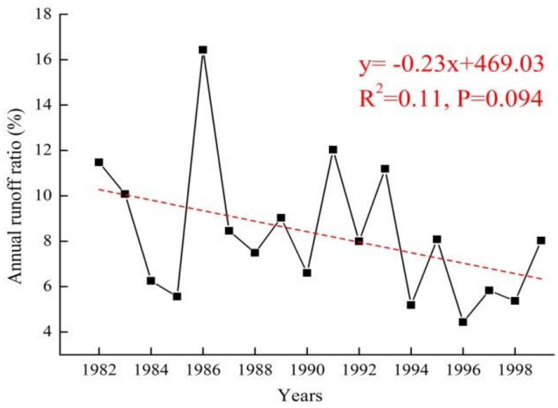

Figure R2.2. Trend of annual runoff ratio during 1982–1999

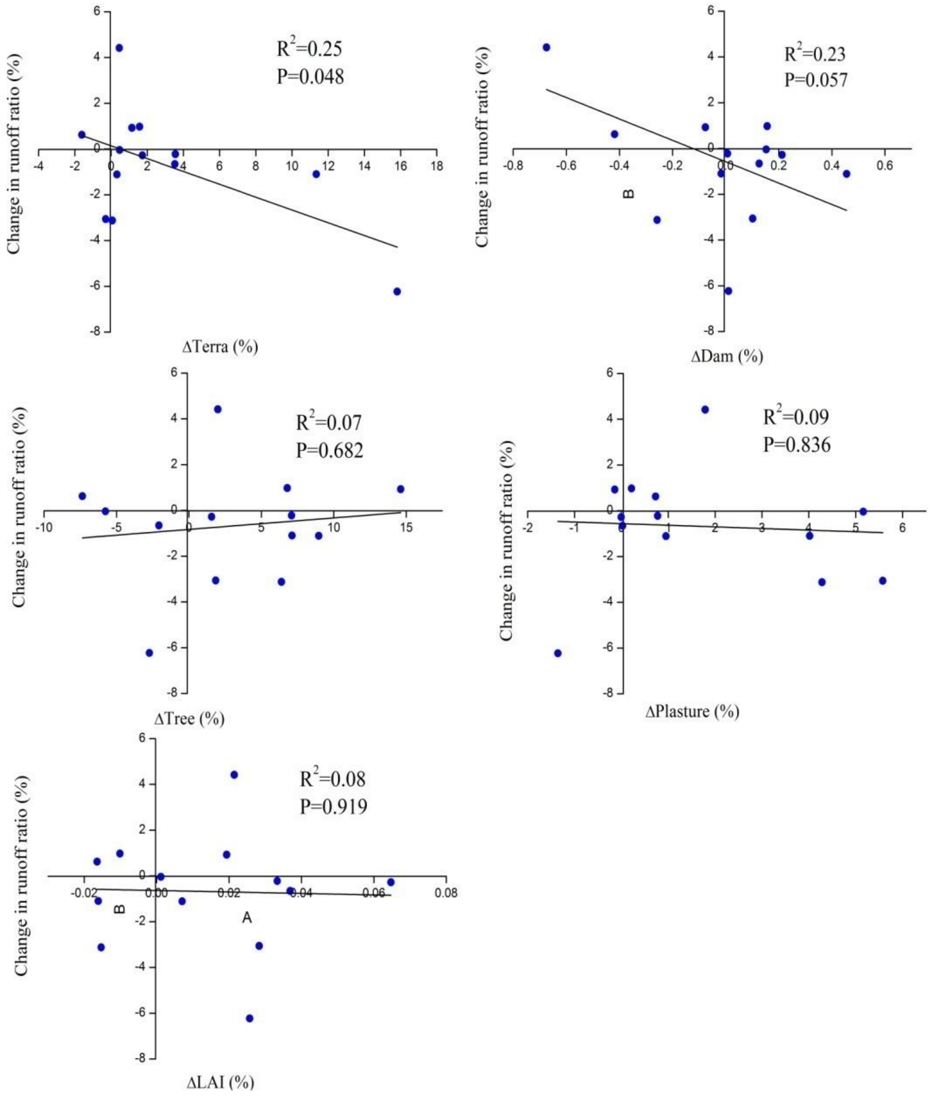

Figure R2.3. Anthropogenic factors of runoff ratio change in 1980s vs. 1990s (ΔTerra, ΔDam, ΔTree and ΔPasture are changes of percentage area for terraces, check-dams, tree planting and natural pasture, respectively. ΔLAI is change of GIMMS LAI for each catchment)

[Reviewer #2 Comment 3]*Section 2.2 The proposed classification method of drought events, drought periods, the interpretations of results, and the upscale processes from 13 sub catchments to regional precipitation anomaly are not clear enough to support the publication of this version of the manuscript in HESS.*

[Response] We thank the reviewer for this comment. We will rewrite section 2.2 to clarify the classification method, and it will appear as followed in the revised MS.

"*In this study, we defined drought based on annual precipitation for two aspects. On the one hand, the amount of precipitation is the most important climatic element necessary as an input into drought (Mishra and Singh, 2010). What's more, we are interested in testing whether the runoff response differs for multiyear droughts, therefore the runoff should not be considered to identify drought.*

We first calculated the precipitation anomaly (PA) in the whole Loess Plateau its separate watersheds, the anomaly series were divided by the mean annual precipitation and smoothed with a 3-year moving average. Positive PAs indicate that the observed precipitation is greater than the median, while the negative PAs is below the median, which implied the drought may occur under this circumstance. Each drought event is characterized by two main properties: drought duration and drought severity. Studies have shown that the drought events with shorter duration but stronger intensity or lower intensity but longer duration would also cause serious water-supply and other drought-related problems (Shiau, 2006; Naresh et al., 2009). Therefore, the basic rules for identifying drought events in this study are (1) A single year's PA ≤ -10% or (2) Mean PAs of more than three consecutive years less than 0, note the start year's PA of the drought period remained a negative value.

Cumulated PAs during the drought period is used to measure the drought severity in this study (for convenience, drought severity is multiplied by -1 to obtain a positive value). Based on the rules above-mentioned, we identified all dry events in each watershed. In order to reflect the response of PRR to drought events over the years, we must ensure that the dry periods are sufficiently long and severe, in the subsequent analysis, we only consider the drought events with drought duration ≥ 5years and *mean annual PA ⩽ -5% during the drought period. Finally, the dry events will be classified two types: the main dry period and the single dry period.*

We used the Kolmogorov-Smirnov (K-S) (Massey, 1951) test to determine whether annual precipitation and runoff data followed an roughly normal distribution, if they did not, they were transformed with a Box-Cox transformation (Box and Cox,1964). After identifying the main drought events, we tested whether the PRR change was statistically significant compared to the historic record using Student's T-test."

[Reviewer #2 Comment 4] *The NPP estimation based on the remote sensing data (2000-2008) could not support the analysis results of the drought on the ecosystem from 1961 to 1999. The authors need to find at least the data in one of the main drought period defined in this manuscript and another normal period to illustrate the difference for determining the drought impacts.*

[Response] We agree with the reviewer that we should find the data that differs between the drought period and the normal period to illustrate the drought impacts. Due to the lack of NPP data before 1999, we will use AVHRR GIMMS LAI3g for the comparison covering long term of 1982–1999 in the revised MS. We choose the drought period of 1991–1999 as an example, we find that LAI significantly (*p*=0.032, Student's T-test) decrease in 1991–1999 compared to that of 1984–1990. We will include this new analysis in the revised MS.

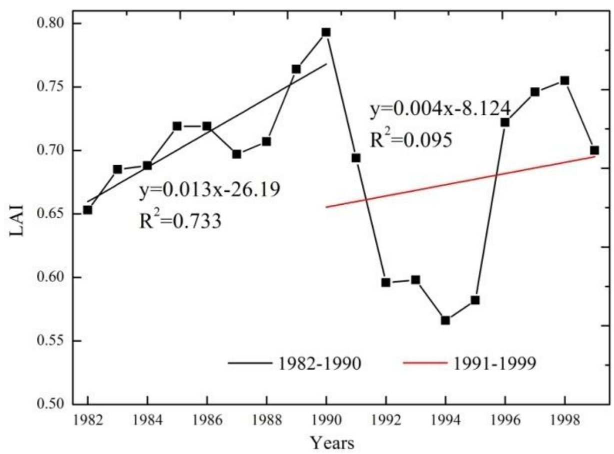

Figure R2.4. Trend of LAI during 1982–1999

[Reviewer #2 Comment 5] *The English should be substantial improved to a certain level that the readers can not misunderstand the correct information.*

[Response] We will ask a native English speaking scientist to help us with the language in revised MS.

Specific comments:

[Reviewer #2 Comment 1] *Affiliation: Shaanxi? should be Shanxi.*

[Response] Affiliation in this manuscript is Shaanxi. Shanxi is a different province in China , which is not related to the MS.

[Reviewer #2 Comment 2] *Page 1, line 1, "is" should be "are".*

[Response] Accordingly, the sentence will be changed to "*The frequency and intensity of drought are increasing dramatically with global warming*."

[Reviewer #2 Comment 3] *Page 1, line 5, only the re-vegetation that makes the drought a major concern?*

[Response] The vegetation restoration programme in China is implemented as the biggest investment to restore the ecosystem in the developing country. The sustainability of vegetation restoration in the Loess Plateau due to the limitation of water is a major concern of scientific research and policy maker in this area (Feng et al., 2016). We will clarify this point in the revised MS.

[Reviewer #2 Comment 4] *Page 1, line 12 delete the "around" after "precipitation"*

[Response] We will delete "around" after "precipitation" accordingly.

[Reviewer #2 Comment 5]*Page 1, line 13-14,"NPP" and "PRR" should not be abbreviation in first appearance.*

[Response] Accordingly, we will change the sentence to "*At the same time, the growth ratio of annual Leaf Area Index (LAI) is also susceptible to prolonged drought, the growth ratio is lower in these watersheds which had a significant change in* *precipitation-runoff relationship (PRR)*". NPP will be replaced with LAI, which the detailed explanation being found in the response to Reviewer #2 general comment 4.

[Reviewer #2 Comment 6] *page 2, line 9-11, weird sentence.*

[Response] We are sorry for the confused expression. The sentence will be changed to "*Soil moisture indicator (Xia et al., 2014), crop drought indicator (Duff et al.,1997) and the crop water demand indicators are used to identify agricultural drought, which is a period with dry soils that results from below-average precipitation, intense but less frequent rain events, or above-normal evaporation and all of these would lead to reduced crop production and plant growth.*"

[Reviewer #2 Comment 7] *Page 2, line 30, replace the "with" with "by".*

[Response] Accordingly, we will revise the sentence as "*so the shift in PPR caused with an extended drought will eventually have an adverse effect on the ecosystem service of water yield.*"

[Reviewer #2 Comment 8] *Page 3, line 25, please indicate the data length or periods.*

[Response] Accordingly, we will clarify in the revised MS that the data length is from 1961 to 1999.

[Reviewer #2 Comment 9] *Page 3, line 27, website in the bracket does not match the text.*

[Response] Following the comment, we will revise the website in the bracket to http://www.yellowriver.gov.cn/.

[Reviewer #2 Comment 10] *Page 4, line 2, replace "its" with "in".*

[Response] Following this comment, we will modify the sentence to "*we first calculated the precipitation anomalies in the whole Loess Plateau in separate watersheds, the anomaly series were divided by the mean annual precipitation and smoothed with a 3-year moving average.*"

[Reviewer #2 Comment 11] *Page 4, line 4, conditions 2 should be page 6, clarified.*

[Response] Accordingly, we will check the condition 2 in Page 4, line 4 in the MS. As one of the basic rules for identifying drought events in this study, we think put it in section 2.2 (Page 4, line 4) is more appropriate.

[Reviewer #2 Comment 12] *Page 6, line 21, please indentify the time period for "long term".*

[Response] Accordingly, we will indentify in the revised MS that the "long term" is for the period of 1961–1990.

[Reviewer #2 Comment 13] *Page 7, line 25-27, long sentence.*

[Response] Accordingly, the sentence in Page 7, line 25-27 will be revised to "D*uring drought period in 1968–1974, the return period was about 7.29 years under the corresponding drought characteristics. So the next drought events similar to drought period in 1968–1974 is happened around in 1980. In 1979–1983, the drought severity reached 0.41, which was close to the predicted return period.*"

[Reviewer #2 Comment 14] *Section 3.3, please re-write the first paragraph.*

[Response] We will re-write the first paragraph in section 3.3 as followed:

"*Fig.5 demonstrates the range of changes in the PRR under sustained precipitation reduction. According to the direction of change, the dry period regression line is mainly located upward or downward the overall regression, the change of the PRR in the studied 13 watersheds show no significant when the regression line of the dry period was above the total regression line. In the 15 times dry events under the regression line in the case of the total regression, there are 9 times significant change in the PRR ($p < 0.05$), accounting for about 60% of the total situation. In this case, the dry period regression line lies lower than nearly all the other points indicating unprecedentedly low runoff generation rates for the given rainfall. Thus in a sequence of years with decreased precipitation, we can conclude that lower runoff not only relate to the lower precipitation, but also less runoff than expected caused by the* *multiyear drought period.*”

[Reviewer #2 Comment 15] *Page 8, line 10, where are the basins with significant changes in precipitation in table 1?*

[Response] We apologized for the confusion. “significant changes” in Page 8 line 10 refers to those watersheds which have a significant change in the PRR. Comparing the annual mean precipitation in separate watersheds during 1961−1999 (Figure R2.5), we can find that multiyear drought is more likely to cause a significant change in the PRR in the basins with less precipitation. We will clarify this point in the revised MS.

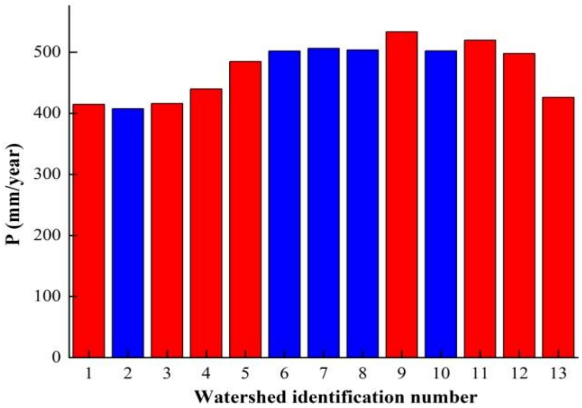

Figure R2.5. Annual precipitation in each catchment

[Reviewer #2 Comment 16] *Page 9, line 5, replace the "as well as " with "and "*

[Response] Accordingly, we will modify the sentence to “*prolonged multi-year drought has caused significant damages both in the natural environments and development of the human societies (Belal et al., 2014).*”

[Reviewer #2 Comment 17] *Page 9, line 11, should be "http://www.mwr.gov.cn"*

[Response] Accordingly, we will revise the website to “http://www.mwr.gov.cn”.

[Reviewer #2 Comment 18] *Figure 1, where is the Yellow river? it is indicated on the up-left small plot that the Yellow river flows through the loess plateau.*

[Response] Yellow River flows through the Loess Plateau. We will add the note of Yellow River on the up-left small plot (Figure R2.6).

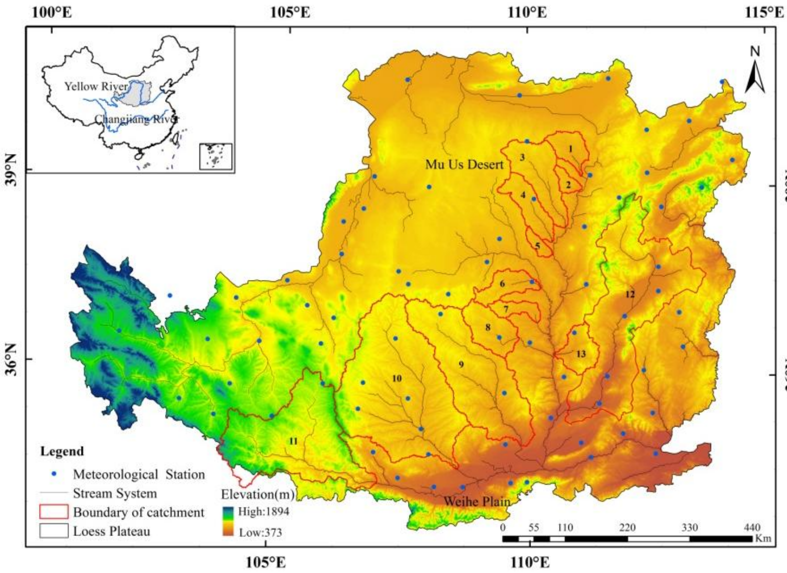

Figure R2.6. The study are

[Reviewer #2 Comment 19] *Figure 2, Do you use the average of rainfall for the 13 watersheds? The description of drought events for condition 1 and 2 in section 2.2 may not be applied on the year 1974, when the 3- year moving average should be lowest in the first main drought period. But the 3-year moving average in 1970 in the figure is lowest.*

[Response] Yes, we used the average of rainfall for the 13 watersheds in Figure 2. After re-examining the calculation of the original data, we found we made a mistake in computing the 3-year moving average. After revising the results, the first main drought period is defined in 1970–1974. As shown in Figure R2.7, the rainfall anomaly in 1974 is -23%, which is accord with the condition 1 in section 2.2. In the first main drought period, the 3- year moving average of 1974 is only smaller than in 1972. We will correct the mistake in the revised MS.

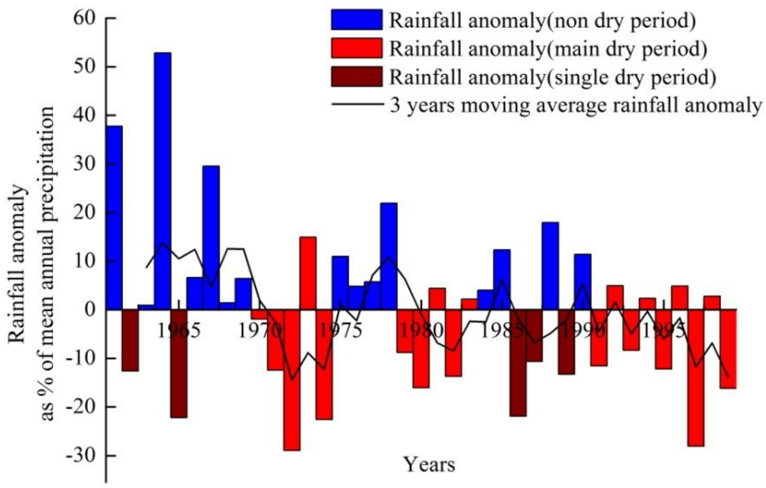

Figure R2.7. average annual precipitation in every catchment

[Reviewer #2 Comment 20] *Figure 3, What are the historical records? Apparently, the historical records in three plots are different, why? better to use the same scale for x-axis in three plots.*

[Response] Historical records in Figure 3 refer to the annual precipitation-runoff scatter plot in a period of 1961–1999 except for a certain main drought period. For example, when the drought occurred in 1970–1974, the corresponding historical record includes precipitation-runoff scatter plot in 1961–1969 and 1975–1999. When the drought occurred in 1991–1999, the corresponding historical record refers to precipitation-runoff scatter plot in 1961–1990. Due to there are three different multiyear dry period in the Loess Plateau during 1961–1999, the corresponding historical records are different in three plots. We will clarify this point in the revised MS and use the same scale for x-axis in three plots in the revised MS as Figure R2.8.

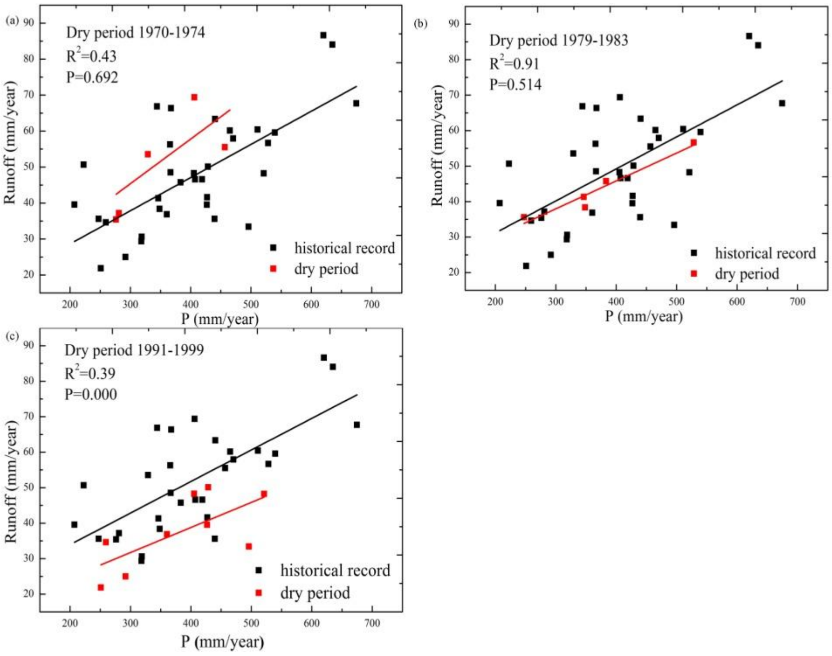

Figure R2.8. Precipitation-runoff relationships during drought periods: (a, b) no significant change in precipitation-runoff relationship and (c) significant downward change in precipitation-runoff relationship.

[Reviewer #2 Comment 21] *Figure 5, the drought periods in different sub-catchments are not identical, why? again, what are these historical records?*

[Response] The drought period is spatial varied, as Figure 5 showed. The drought period of each catchment is identified with the local data of precipitation and change of precipitation-runoff relationship.

Similar with Figure 3, the historical records refer to the annual precipitation-runoff scatter plot in a period of 1961–1999 except for a certain main drought period, which the detailed explanation being found in the response to Reviewer #2 comment 20.

[Reviewer #2 Comment 22] *Figure 7, what is the drought event corresponding to the return period in figure7d?*

[Response] The drought event corresponding to the return period in figure 7d is drought duration and severity that caused a significant change in the PRR in 8 watersheds. We will clarify this point in the revised MS.

[Reviewer #2 Comment 23] *Figure 8, at least show the whole legend of the figure 8a. is it the average return period of the drought events in 8b?*

[Response] Following this comment, we will show the whole legend of the figure 8a in the revised manuscript. It is the average return period of the drought events in 8b. We will clarify in the revised MS as "*Based on the spatial distribution of drought events in the Loess plateau, the 13 watersheds were further divided into four regions. Similarly, we calculated the return period in these four regions according to their main dry periods during 1961–1999, and showed the average return period of the drought events in 8b.*"

[Reviewer #2 Comment 24] *Figure 9, add "change" after the significant in the caption.*

[Response] Accordingly, we will add "change" after the significant in the caption of Figure 9.

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