

## Response to HESS-2019-8-RC2

### Anonymous Referee #2

Thanks for your suggestions. We appreciate for anonymous referee comments concerning our manuscript entitled "Dissolved Organic Carbon Driven by Rainfall Events from a Semi-arid Catchment during Concentrated Rainfall Season in the Loess Plateau, China". We have studied comments carefully and have made corrections. The main corrections in the manuscript according to the referee's comments are as follows:

**Comment 1.** L43-50: these piled data didn't give a clear background on DOC export. They should be re-organized and present in term of different catchment characteristics.

**Response:** Thanks for your suggestions. These sentences of the introduction have been re-written in Line 40-59 as detail shown as following:

**Line 40-57:** DOC exported from catchments has attracted great attention in the last two decades due to global concerns about potential influences on the global carbon cycle and climate change (Laudon et al., 2004; Raymond et al., 2013). **The transport of terrestrial DOC to runoff is strongly influenced by hydrological process, soil carbon cycle and climatological factors. Hydrological process driven by rainfall event plays an important role in controlling terrestrial DOC from soil pool to runoff. Previous studies have shown that the release of DOC concentrations ranged from 0.5 to 50 mg L<sup>-1</sup> for global catchments (Mulholland, 2003).** For instance, Clark et al. (2007) found that DOC concentration ranged between 5-35 mg L<sup>-1</sup> with a highly variable in rainfall events from a peatland catchment, and a study by Blaen et al. (2017) showed that the DOC concentration ranged from 5.4 to 18.9 mg L<sup>-1</sup>. Similar results were reported by Ran et al. (2018), who found that DOC concentration ranged from 1.4 to 9.5 mg L<sup>-1</sup> in the Wuding River in the LPR. Such studies highlighted that the importance of hydrological process on DOC transport (Billett et al., 2006; Dawson et al., 2002; Inamdar et al., 2006). **Different rainfall events may alter hydrological connectivity or the flow path, which in turn lead to a varied hydrological connectivity and DOC source contributing to runoff. Moreover, the intensity and frequency of rainfall event not only influenced the current hydrological and DOC loading processes, but also changed the soil moisture conditions. The latter point may be particularly important in soil biogeochemical cycle.** For example, DOC concentration may increase due to accumulated soil organic carbon after a dry period (Jager et al., 2009). In addition, variations in the magnitude and frequency of precipitation are one of manifestations of climate change, and thus, changes in hydrological process induced by climate change are also impact on the transport of terrestrial DOC. Therefore, understanding the dynamic and magnitude of DOC export from catchment is an important component of prediction DOC flux under the circumstance of future climate change.

**Comment 2.** The knowledge gap is not well stated.

**Response:** Thanks for your suggestions. The knowledge gap and objective part has been reorganized as following:

**Line 69-79:** Less information is available on DOC export driven by rainfall event, which DOC flux is an important component in overall carbon balance for ecological restored catchment.

Therefore, the primary goal of this study is to investigate how variations of DOC concentration and flux response to a sequence of rainfall events from a restored catchment during concentrated rainfall season in the LPR. Specifically, the two objectives of this study were (1) to examine the dynamic changes in DOC concentration and flux and assess the difference in DOC export driven by various rainfall events, and (2) evaluate how rainfall, runoff, and antecedent factors affect DOC export from a catchment. To do so, we used high-frequency method to capture the temporal changes in DOC export and hydrological process driven by rainfall event within an ecological restored watershed in LPR. These results will provide evidence of DOC export response to rainfall events, especially driven by extreme events, which may be important for evaluating carbon balance and modeling DOC export through runoff at ecological restored catchment in LPR.

**Comment 3.** Be more specific about the experiment duration. How long/how many rainfall events have you been monitoring and sampling?

**Response:** Thanks for your suggestions. Line 108-109 added the sampling information.

**Line 108-109:** There were 278 samples collected for 22 hydrological processes induced by rainfall event over the monitoring period of June to September, 2016.

**Comment 4.** The author should either consider combining the result and discussion sections OR separating them clearly in the writing. There are multiple places that the results been re-stated in discussion or discussed the result right after without citation.

**Response:** Thanks for your suggestions. Some sentences in discussion part has been moved to the results part and details showed as following:

**Line 168-169:** In addition, Figure 4-a showed the relationship between flow rate and rainfall amount during June to September.

**Line 169-170:** This indicated that event-driven flow rate varied with rainfall amount, and thus suggested that runoff discharges are highly sensitive to larger rainfall amount with greater than 20 mm in this area.

**Line 179-182:** Table 2 showed the correlation between  $C_f$  and a set of factors in all sampled rainfall events during the study period. On one hand, the  $C_f$  was positively correlated with rainfall amount (Ra) and R7. On the other hand, the  $C_f$  was extreme significantly and negatively correlated with

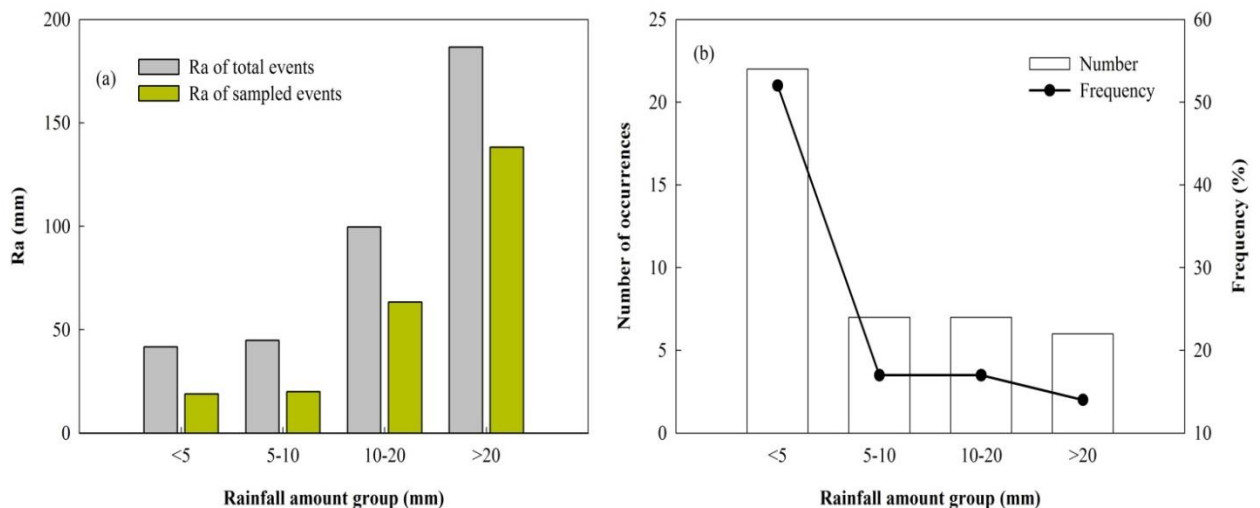
**Line 214-217:** The relationship between event-based DOC flux and runoff discharge amount is shown in Figure 4-c. The DOC flux showed a positive linear relationship with the runoff discharge amount, especially for violent rainfall events. The DOC flux was more variable in lower runoff discharge conditions. In general, event-based DOC flux was significantly and positively correlated with Q, Ra, R1 and R, as showed in Table 2.

**Comment 5.** I'm confused with the way you separate the rainfall events into 4 groups. In Figure 3 you stated in x-axis was rainfall intensity, but the unit was mm, not mm/h. Why do you define rainfall intensity based on accumulated rainfall depth? In the Yang et al. (2018) paper you referred, they denoted the rainfall replenishment in mm to effectively recharge the soil water.

**Response:** Thanks for your suggestions. Indeed, the rainfall events were grouped by rainfall amount and the Figure 3 has been changed. According to Yang's results, the threshold of rainfall amount mean rainwater can effectively recharge the soil water in LPR, which may affect soil moisture content. This is why we selected this classification. Thus, we choose the parameter of rainfall amount to analyze in this manuscript.

**Line 156-158:** All the rainfall events in between June to September were grouped into four grades: <5 mm (Light rainfall), 5-10 mm (Moderate rainfall), 10-20 mm (Heavy rainfall), and >20 mm (Violent rainfall) according to rainfall amount classification (Yang et al., 2018).

**Figure 3:**



**Line 246-260:** Despite the facts that the DOC export varied in different months, there were also differences in DOC concentration and flux response to a rainfall event. DOC concentrations exhibited different dynamic changes throughout an event-driven hydrological process. In our result, the anticlockwise hysteresis between DOC concentration and flow rate was observed at 6-June. The peak DOC concentration was delayed compare to peak flow rate. These results may be attributed to a 5.2 mm

rainfall was happen earlier than the maximum rainfall at 6-June (Figure 5-a). The antecedent rainfall may increase connectivity in hydrology and DOC source contributed to runoff. Thus, the dilution effect diminished as flow rate decreased and the increased connectivity lead to a relatively higher DOC concentration during the falling limb (Hope et al., 1994; Ma et al., 2018; Williams et al., 2017). A clockwise hysteresis was observed in 13-July and 10-September. The rapid response of flow rate to rainfall can be attributed to the rainfall event with a shorter duration and larger rainfall amount. The higher discharge may bring a higher flushing capacity, thus an increased DOC concentration was observed during the rising limb (Blaen et al., 2017; Tunaley et al., 2017). Moreover, the close link of DOC source to runoff may lead to a rapid increased in DOC concentration. A figure-of-eight hysteresis was observed in 2-August. due to the DOC concentration keep pace with flow rate during the rising and falling limb. Moreover, the event-driven DOC concentration at 2-August showed no distinct difference with other three higher rainfall amount events. These results suggested that a lower discharge induced by lower rainfall amount have a more complex and larger influence on DOC concentration from a catchment in LPR.

**Comment 6.** The major finding you stated was higher DOC export with low DOC concentration. I have several questions about this finding: In Figure 4, you stated DOC concentration depressed with increased discharge for greater intensity.

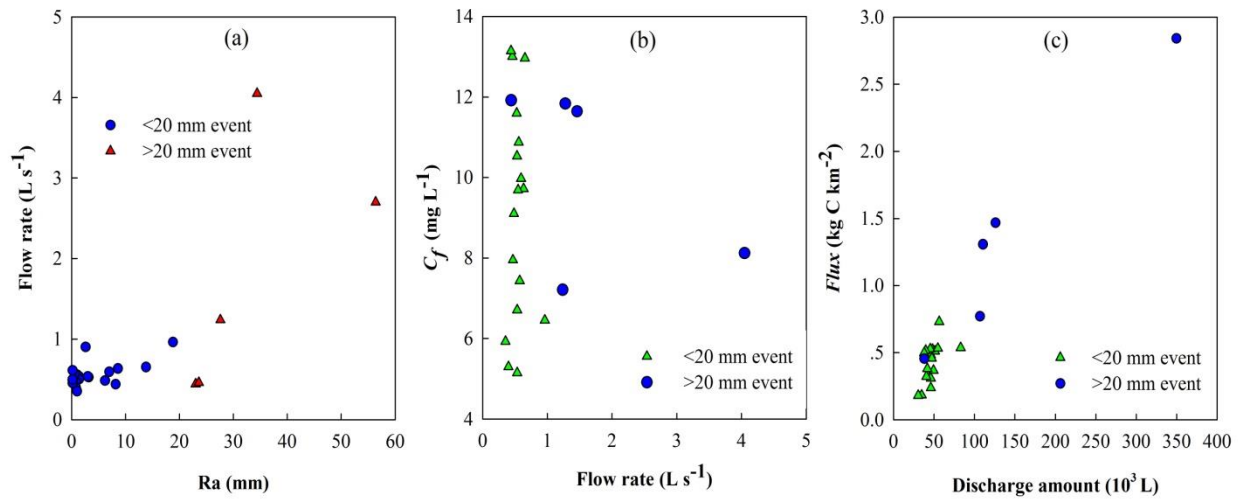
**Response:** Thanks for your suggestions. The conclusion has been rewritten as following:

**Line 321-324:** These results showed that higher DOC flux with low DOC concentration related to higher discharge and its dilution effects in a hydrological process driven by larger rainfall amount. The diluted DOC concentration induced by increased discharges contributed slightly to difference in DOC flux, due to total runoff discharge is a major variable for flux.

**Comment 7.** How are you sure since you only have 5 points with  $r^2$  value of 0.38. Is this correlation significant? In Figure 5, DOC do show positive relationship with discharge within individual event, how do you explain this contrary?

**Response:** Thanks for your suggestions. The regression has been removed. The results shown in Figure 5 has been reorganized in discussion part:

**Figure 4**



**Comment 8.** L32: insert a summary sentence before “For instance, high DOC. . .”. The following statements come from nowhere and it’s confusing.

**Response:** Thanks for your suggestions. The first paragraph in introduction has been reorganized and the details show in Line 28-39 of this manuscript:

**Line 28-39:** Dissolved organic carbon (DOC), often defined as the solute filtered through <0.45μm pore size, is regarded as one of the active constituents and provides a biologically available carbon source for organisms (Raymond and Saiers, 2010). **The estimated DOC flux of terrestrial organic carbon through major worldwide rivers to ocean is from 0.45 to 0.78 Pg C y<sup>-1</sup>**(Drake et al., 2018; Hedge et al., 1997; Ran et al., 2018). **The substantial magnitude of flux suggests that the DOC export on a global scale acts as one of the crucial processes of linking between terrestrial and aquatic ecosystem** (Battin et al., 2008; Raymond et al., 2013; Raymond and Saiers, 2010). For instance, high DOC concentrations can lead to water pollution and eutrophication, and thus have dramatic consequences on aquatic ecosystem services (Evans et al., 2005; Hu et al., 2016). **In addition to ecological impacts, DOC in runoff also play an important role in social well-beings.** High DOC concentrations will aggravate the complexation and adsorption of pesticides and heavy metals in hydrological process. Therefore, the quality of domestic water could be damaged and it might potentially lead to adverse impacts on human health, such as increased risk of cancer, diabetes, or other diseases (Bennett et al., 2009; Ritson et al., 2014). Therefore, it is urgent to improve the associated knowledge on DOC export variability and develop a mechanistic understanding of DOC export from catchments.

**Comment 9.** give the time period for average annual temperature and precipitation. Is 535 mm only coming from rainfall or also including other type of precipitation?

**Response:** Thanks for your suggestions. We have added some information about the precipitation and details show in the following:

Line 86-88: The climate of this catchment is situated in a semi-arid continental monsoonal climate with an average annual temperature of 9.6°C and average annual precipitation is 535 mm during the period from 1951 to 2012 (Li and Wang, 2015).

**Comment 10.** state specific land alteration in “represent an area with altered land use that has. . .”

**Response:** Thanks for your suggestions. These details show in Line 92-94 of this manuscript

**Line 92-94:** The proportion of sloping cropland has remarkably decreased from 16.9% in 1998 to 0.1% in 2006. The forestland increased from 15.2% in 1998 to 37.4% in 2006 since implemented the 'Grain-for-Green' and engineering measures (Wang et al., 2011b).

**Comment 11.** the part “In addition, the aim of hydrological. . .” should be stated before you introduce the meteorological station, and also should be condensed.

**Response:** Thanks for your suggestions. The sentence has been moved forward to Line 109-110.

**Line 109-110:** In addition, the aim of hydrological and meteorological factor monitoring was to characterize the temporal changes of catchment condition.

**Comment 12.** L133: “microbiologically biodegrade” to “microbially degrade”.

**Response:** Thanks for your suggestions. The “microbiologically biodegrade” has been changed to “microbially degrade” in Line 118-119.

**Line 118-119:** In the Yangjuangou catchment, researchers resided in the field observatory station and treated the samples immediately after a rainfall event to ensure that the DOC in the sampled water did not microbially degrade.

**Comment 13.** L138-L140: give CV of procedure accuracy.

**Response:** Thanks for your suggestions. We added the CV of procedure accuracy in Line 127-128:

Line 127-128: In order to control quality, each sample is determined through analysis of two replicate and the coefficient of variation of tested results was less than 10%.

**Comment 14.** L149-L156: this section should be in laboratory analysis or an independent section rather in data analysis.

**Response:** Thanks for your suggestions. The section has been reorganized

**Line 129-152:**

## 2.4 Data Analysis

### 2.4.1 Event-driven DOC Concentration and Flux Calculation

### 2.4.2 Variables related to Event-driven DOC Transport

### 2.4.3 Statistical analysis

**Comment 15.** L166: “in June to September” to “in between June and September”.

**Response:** Thanks for your remind.

**Line 156-158:** All the rainfall events in **between** June to September were grouped into four grades: <5 mm (Light rainfall), 5-10 mm (Moderate rainfall), 10-20 mm (Heavy rainfall), and >20 mm (Violent rainfall) according to rainfall amount classification (Yang et al., 2018).

**Comment 16.** L186: I suggest to open this paragraph with sentence “In general, runoff discharge tended to follow the pattern of rainfall amount in the study catchment.”

**Response:** Thanks for your suggestions. we changed at the beginning of this paragraph in Line 163:

**Line 163:** **In general, runoff discharge tended to follow the pattern of rainfall amount in the study catchment.**

**Comment 17.** L189: where did the value “34.70 mg L<sup>-1</sup>” come from? I didn’t see this value in Figure 2 or Figure 5.

**Response:** Thanks for your remind. The value has been changed in Line 175-176:

**Line 175-176:** For the event-driven DOC concentration, the flow-weight mean DOC concentration ( $C_f$ ) ranged from **4.08 to 15.66 mg L<sup>-1</sup>** for all sampled rainfall events during June to September.

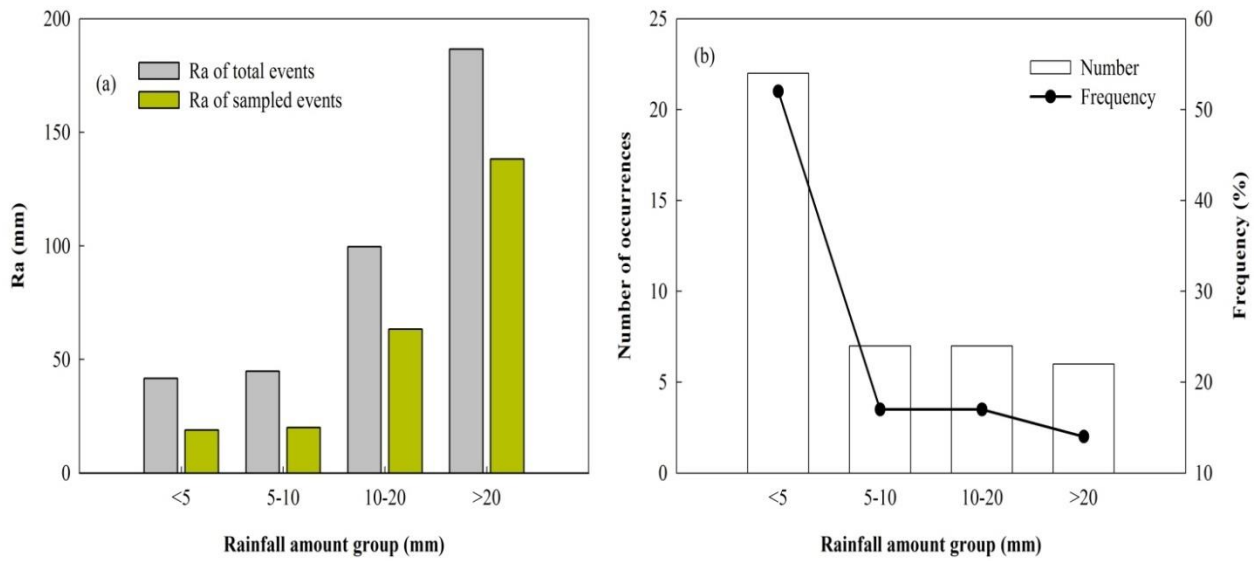
**Comment 18.** L191: “DOC concentration were less variable during June to September”, less compare to what?

**Response:** Thanks for your suggestions. We revised this sentence in Line 185-186:

**Line 174-175:** There were less variations in the mean DOC concentration **among monitoring months.**

**Comment 19.** Figure 3: see previous comments about the grouping.

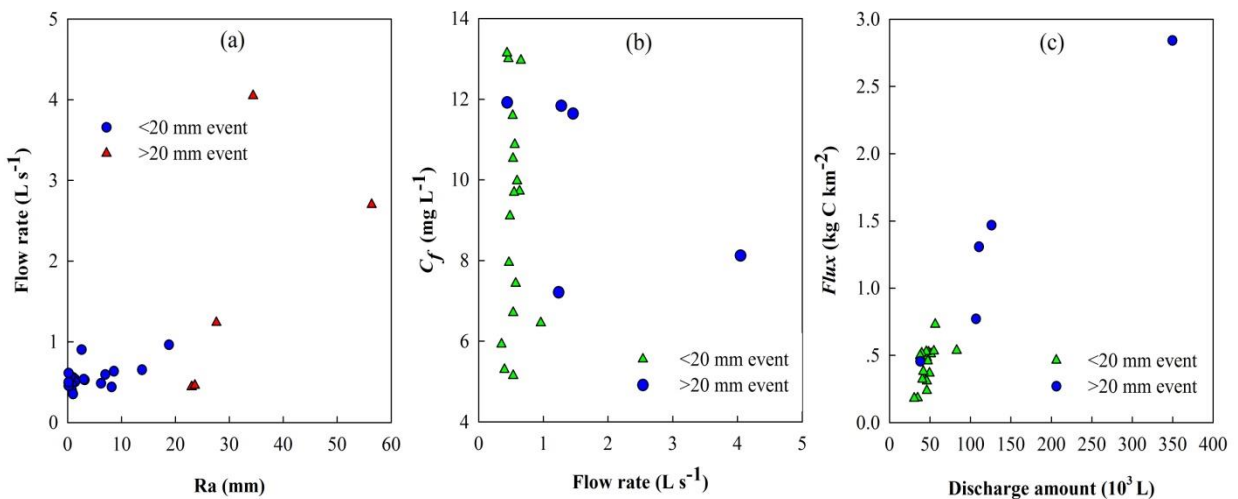
**Response:** Thanks for your suggestions. The rainfall events were grouped by rainfall amount and the Figure 3 has been changed.



**Comment 20.** Figure 4: Is the second figure necessary? DOC flux is calculated based on discharge. Why present a variable that is highly dependent on the other variable?

**Response:** Thanks for your suggestions. Thanks for your suggestions. For the Figure 4-c, we removed the relationship between DOC flux and discharge amount due to the flux was calculated by discharge amount. Thus, the regression has been removed and the details shown as following:

**Figure 4**



**Comment 21.** Figure 5: explain in result section why did you choose these four events? Do they show different rainfall intensity? Axis of DOC concentration could be in the same scale.

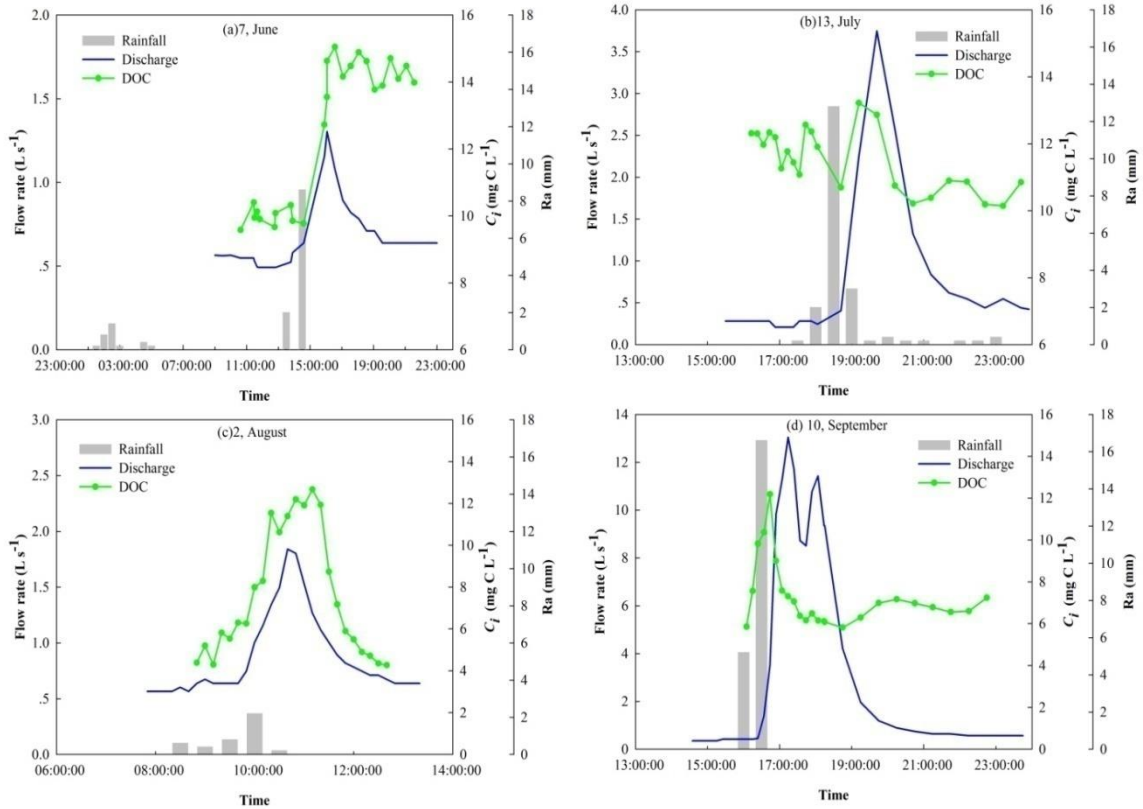
**Response:** Thanks for your suggestions. Line 184-186 has been added and explained why we



choose these four events. The axis of DOC concentration in Figure 5 has been change to the same scale.

**Line 184-186:** Four rainfall events of total sampled events were chosen for detailed examine the relationship between DOC concentration ( $C_i$ ) and flow rate in the hydrological process. These selected rainfall events represented 83% of the occurrence frequency of rainfall amount and the collected samples with high-frequency cover a complete of hydrological process during the monitoring period.

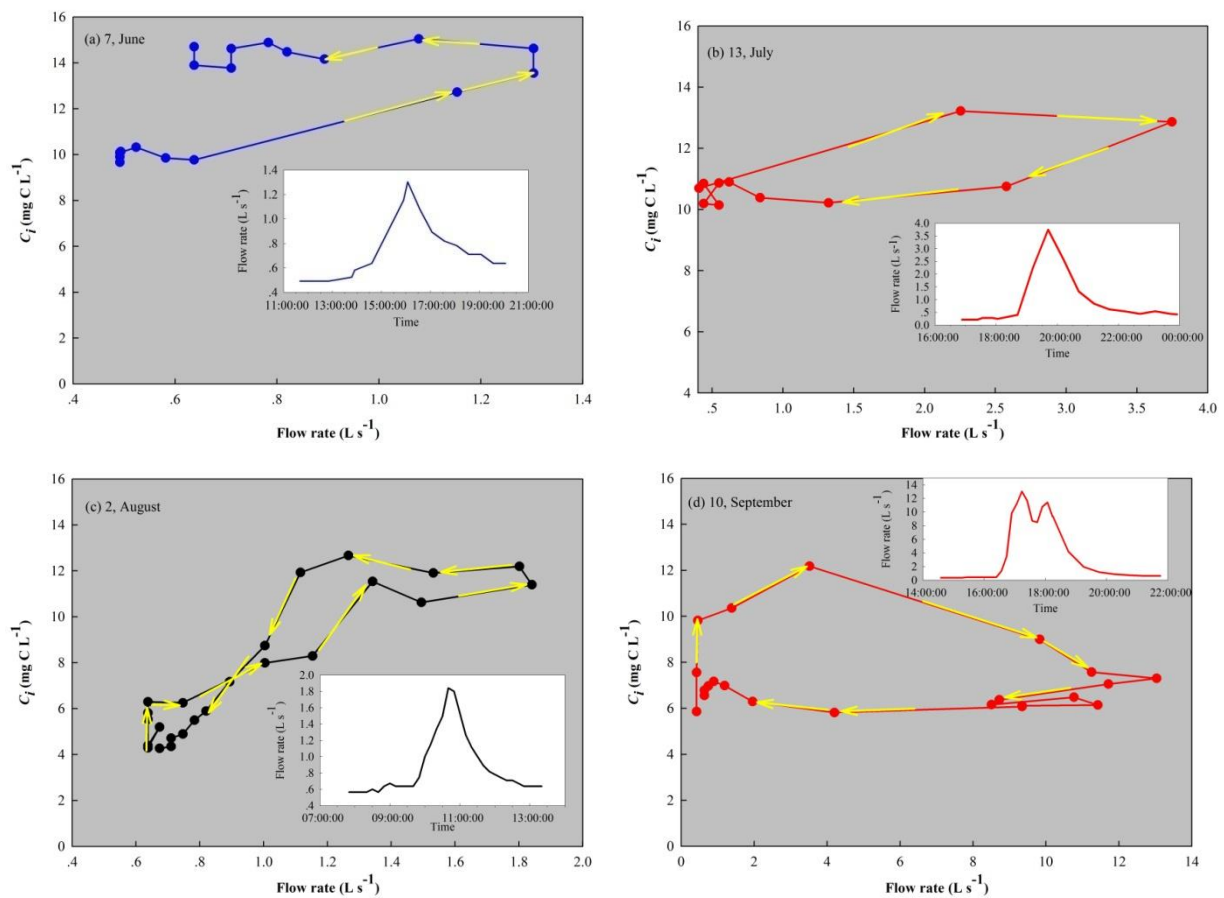
**Figure 5**



**Comment 22.** Figure 6: Axis of DOC concentration could be in the same scale.

**Response:** Thanks for your suggestions.

**Figure 6**



### Other Changes:

We have revised the abstract part in Line 11-26 and the conclusion part in Line 324-331. We also added discussion information in Line 261-271 and Line 304-314. The details show in the following part:

**In Abstract Line 11-26:** Dissolved organic carbon (DOC) transported by runoff has been identified as an important role of the global carbon cycle. Despite there being many studies on DOC concentration and flux, but little information is available in semi-arid catchments of the Loess Plateau Region (LPR). The primary goal of this study was to quantify DOC exported driven by a sequence of rainfall events during the concentrated rainfall season. In addition, factors that affect DOC export from a small headwater catchment will be investigated accordingly. Runoff discharge and DOC concentration were monitored at the outlet of the Yangjuangou catchment in Yanan, Shaanxi Province, China. The results showed that DOC concentration was highly variable, with event-based DOC concentrations ranging from 4.08 to 15.66  $\text{mg L}^{-1}$ . Hysteresis analysis showed a nonlinear relationship between DOC

concentration and flow rate in the hydrological process. The monthly DOC flux loading from the catchment was 94.73-110.17 kg km<sup>-2</sup> from June to September, while the event-based DOC flux ranged from 0.18 to 2.84 kg km<sup>-2</sup>. Variations of event-driven DOC concentration contributed slightly to a difference in DOC flux, whereas intra-events of rainfall amount and runoff discharge led to evident difference in DOC export. In conclusion, our case results highlighted the advantages of high-frequency monitoring for DOC export and indicated that event-driven DOC export is largely influenced by the interaction of catchment hydrology and antecedent condition within a catchment. Engineering and scientists can take advantage of the derived results to better develop advanced field monitoring work. In addition, more studies are needed to investigate the magnitude of terrestrial DOC export in response to projected climate change at larger spatiotemporal scale, which may have implication for the carbon balance and carbon cycle model from an ecological restored catchment in LPR.

**Line 261 -271:** For event-driven flux, the DOC flux is a function of total runoff discharge and DOC concentration ( $C_f$ ). DOC flux showed a positive linear relationship with runoff discharges, which is not surprising and parallel with studies reported by Clark et al. (2007) and Ma et al. (2018). In addition, it should be noted that the DOC flux induced by larger rainfall amount was higher than flux driven by light rainfall, whereas the  $C_f$  showed no evident difference for the selected rainfall events. Thus, the greater DOC flux clearly showed that the DOC export was close linked to hydrologic process induced by various amount of rainfall event in LPR. For an ecological restored catchment in LPR, the soil carbon driven by increased vegetation was significantly increased and acted as a positive pathway to sequestration soil carbon on terrestrial ecosystem (Wang et al., 2011b). Meanwhile, the reduced hydrology responded to an increased vegetation may diminish soil carbon transported by hydrological process in a catchment. The event-driven DOC transport is an important component for evaluating carbon balance of the ecological restored catchment in LPR. Hence, further study should be long-term undertaking to investigate the hydrological response and its impact on terrestrial carbon loss from a catchment in LPR.

**Line 304-314:** DOC flux was significantly and positively correlated with Q, Ra, R1 and R7. The Q and Ra reflect the direct effect of current rainfall and hydrological processes during a rainfall event, while R1 and R7 refer to the antecedent rainfall conditions and reflect indirect effects on DOC export. These results agreed with previous studies demonstrated by Blaen et al. (2017), who noted that antecedent conditions and rainfall were key drivers of DOC export during a rainfall event. Cooper et al. (2007) also concluded that DOC export is largely governed by interactions between hydrological and meteorological factors and carbon biogeochemical process. Overall, these results suggested that rainfall is a key factor influencing hydrological process, and thus DOC export from an ecological restored catchment in LPR. Apart from the increased soil carbon driven by increased vegetation (Wang et al., 2011b), the weaken hydrological process induced by increased vegetation may also cause a less terrestrial carbon export from a catchment. Therefore, our results highlight the need for research not only into the hydrological process and soil carbon cycle, but the integration of carbon export driven by a sequence of rainfall events across spatiotemporal scales to understand the carbon balance in a restored catchment in LPR.

**Line 324-331:** These results showed that the temporal variation magnitude of DOC is related to hydrological condition and antecedent condition, and suggested that the event-driven DOC export is largely influenced by rainfall through direct effects on catchment hydrology and indirect effects on soil carbon cycles. Changes in catchment hydrology and soil carbon processes responded to climate change may play an important role in terrestrial carbon export, in particular for a restored catchment. Thus, further work should focus on carbon export response to various rainfall events at a larger spatiotemporal scale for better estimating future terrestrial carbon flux to aquatic ecosystem and evaluating carbon balance in ecological restored catchment in LPR. In addition, engineers and scientists can take advantage of the derived results to better develop advanced field monitoring work.