Response to HESS-2019-8-RC1

Anonymous Referee #1

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. Please illustrate the influences of DOC on the aquatic environments and climate change before enumerating the concentration ranges of DOC in different regions.

Response: Thanks for your suggestions. Line 33-36 describe the potential influence of DOC.

Line 33-36: 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.

Comment 2. The previous paper about DOC export in the Loess Plateau should be presented in a more concise way and it is better to combine the lack of previous research and put forward your own hypothesis.

Response: Thanks for your suggestions. The lack of previous research and objective part has been rewritten and the details show in Line 69-79 of this manuscript:

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. Please introduce the time/period of sampling or monitoring, how much rainfall events were monitored and how many samples were collected in the section of Field Monitoring and Sampling. The specific rainfall events mentioned in 3.2.2 and the reason for selecting these events should also be explained in 2.2.

Response: Thanks for your suggestions. Line 108-109 added the sampling information and Line 184-186 added the reason for selecting rainfall events.

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.

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.

Comment 4. Please complete the name of the TOC analyser, like Vario TOC select or Vario TOC cube. I think it would be much better to describe what the 1% H_3PO_4 solution is used for.

Response: Thanks for your suggestions. These details show in Line 124-128 of this manuscript.

Line 122-126: DOC was recognized as the difference between total dissolved carbon (TDC) and dissolved inorganic carbon (DIC) for each sample (DOC=TDC-DIC). TDC and DIC were determined by Vario Select (Elementar, Germany), which included a high-temperature combustion furnace, a self-contained acidification module and a highly sensitive CO_2 detector. TDC was automatically measured by the combustion of a sample, whereas DIC was measured after acidified by 1% H_3PO_4 solution (phosphoric acid).

Comment 5. The meaning of DOC concentration and discharge should be consistent throughout the paper. DOC concentration has been defined as the flow-weighted mean DOC concentration. Ci and Qi were defined as the discharge and DOC in an individual runoff sample. However, the Y-axis in figure 5 corresponds to the discharge and DOC concentration of each sample. It is better to present flow-weighted mean DOC concentration in another way to distinguish it from the DOC in runoff samples and DOC in other studies.

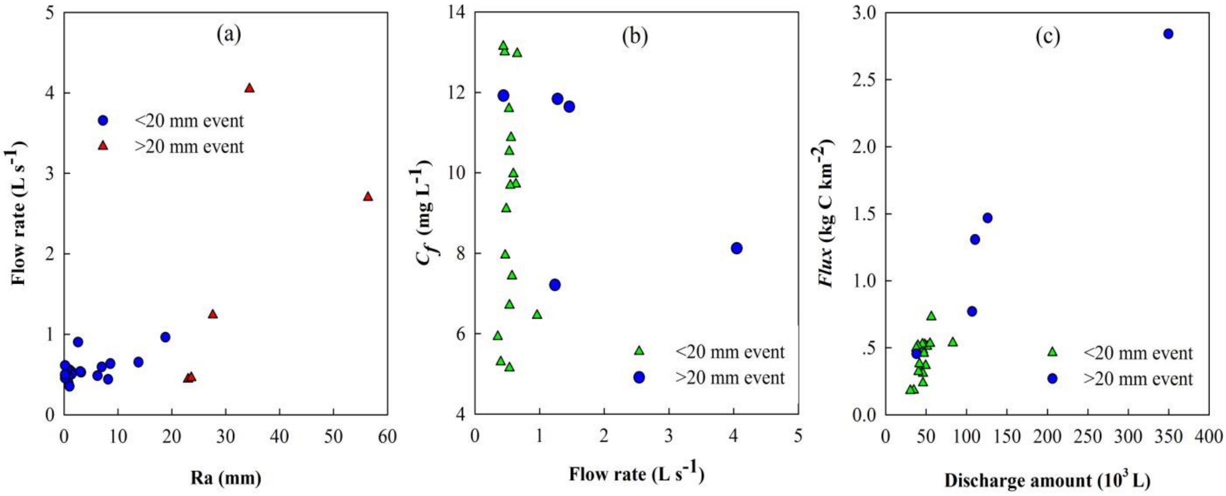
Response: Thanks for your suggestions. In order to differentiate event-based DOC concentration and instant DOC concentration, these details have been changed in text and figures.

Line 131-132: In the present study, the flow-weight mean concentration **(C_f)** was used to determine the average DOC concentration in a rainfall event. C_f was calculated by dividing the total DOC load by the total discharge in an event time.

Line 136-137: where, Qi (L) is the discharge amount corresponding to sample i, which was calculated by flow rate and interval time; C_i (mg L^{-1}) is the DOC concentration in a runoff sample i;

***C_f* in Y axis of Figure 4-b:**

Figure 4



***Ci* in Y axis of Figure 5 and Figure 6**

Figure 5

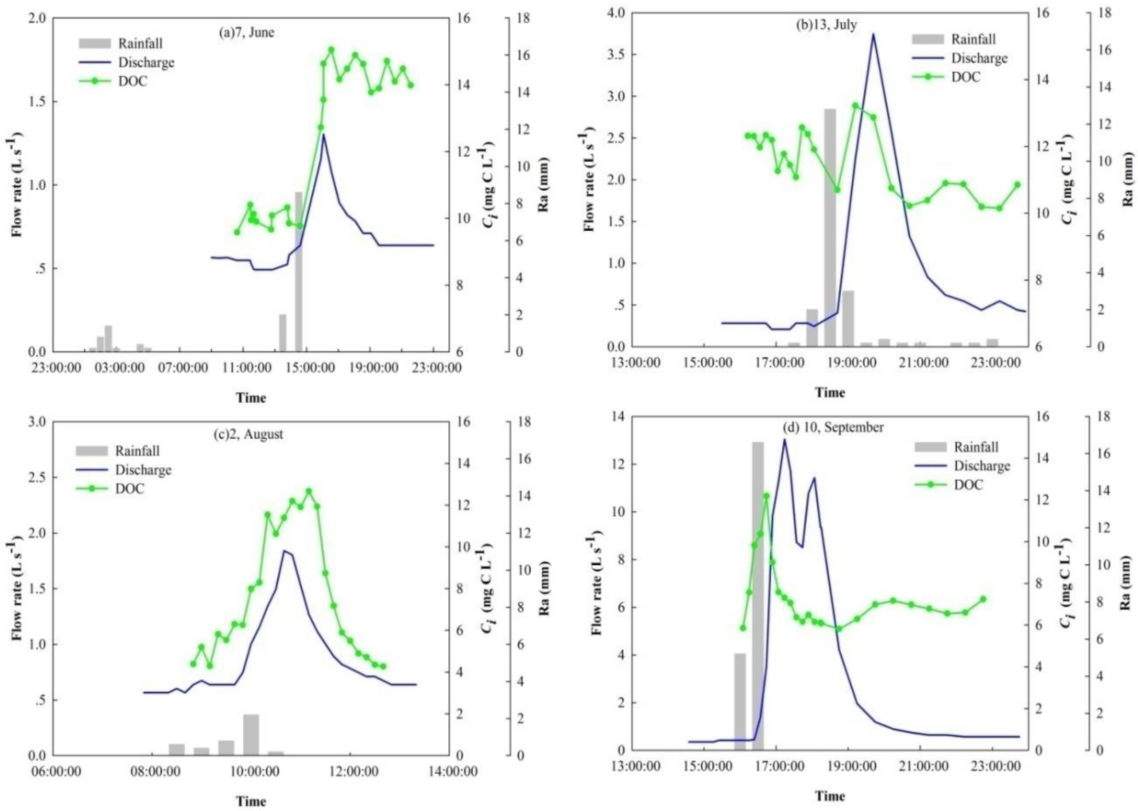
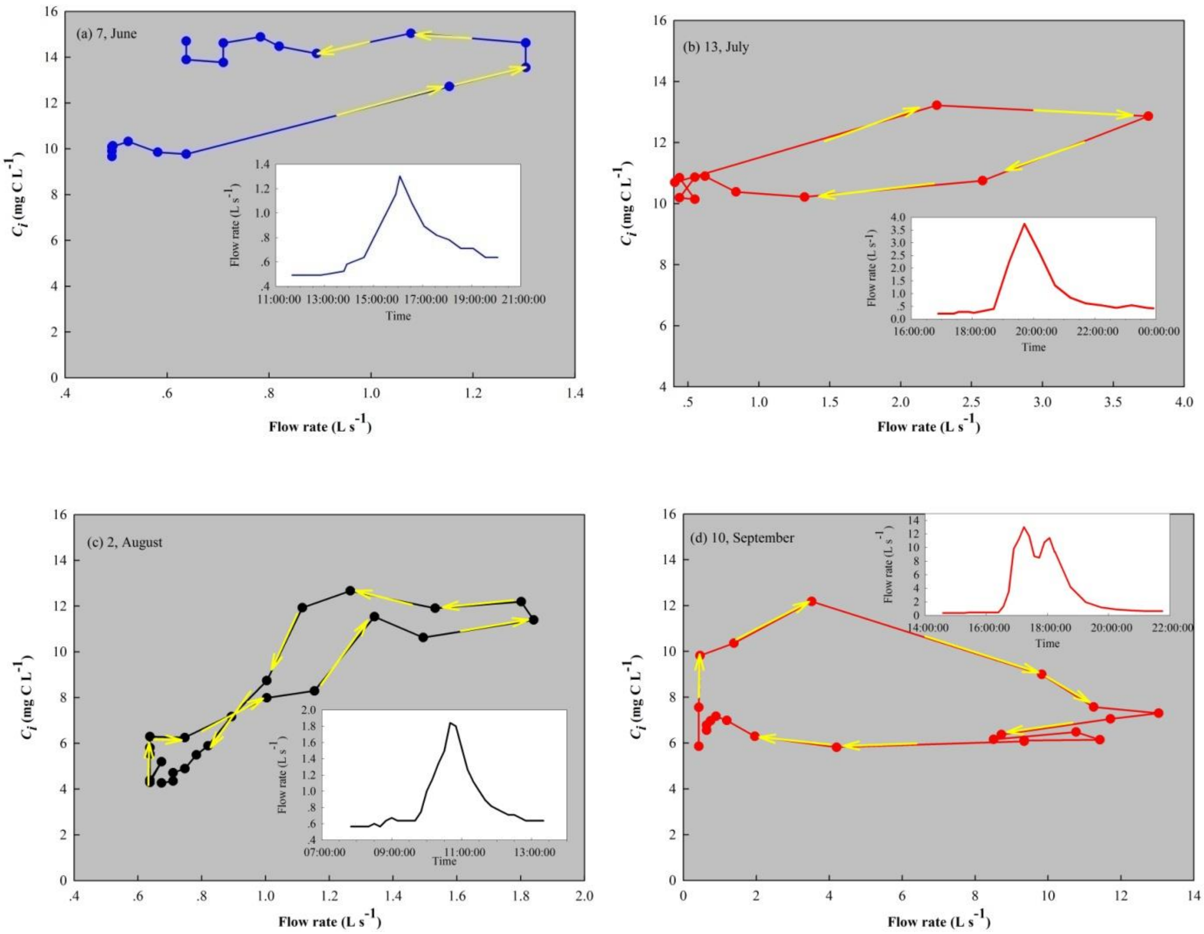


Figure 6



Comment 6. It would be better to use commas instead of semicolons. There should be a space between "7" and "and" (line 155-156). Do not use a colon to explain abbreviations (line 156).

Response: Thanks for your remind. The details have changed in Line 143-147:

Line 143-147: These variables are Q (total discharge volume a rainfall), Ra (total rainfall amount in a rainfall event), R1, R7 and R14 (total rainfall amount in the 1, 7 and 14 days before the current rainfall event, respectively), SMC-7 and SMC-14 (soil moisture content in the 7 and 14 days before the current rainfall event), T_{air}-7 and T_{air}-14 (mean air temperature in the 7 and 14 days before the current rainfall event) and REI (interval days between the current and last rainfall event).

Comment 7. Please use the version information of SPSS instead of Statistics Package for Social Science.

Response: Thanks for your remind. We have added the information in Line 149-151.

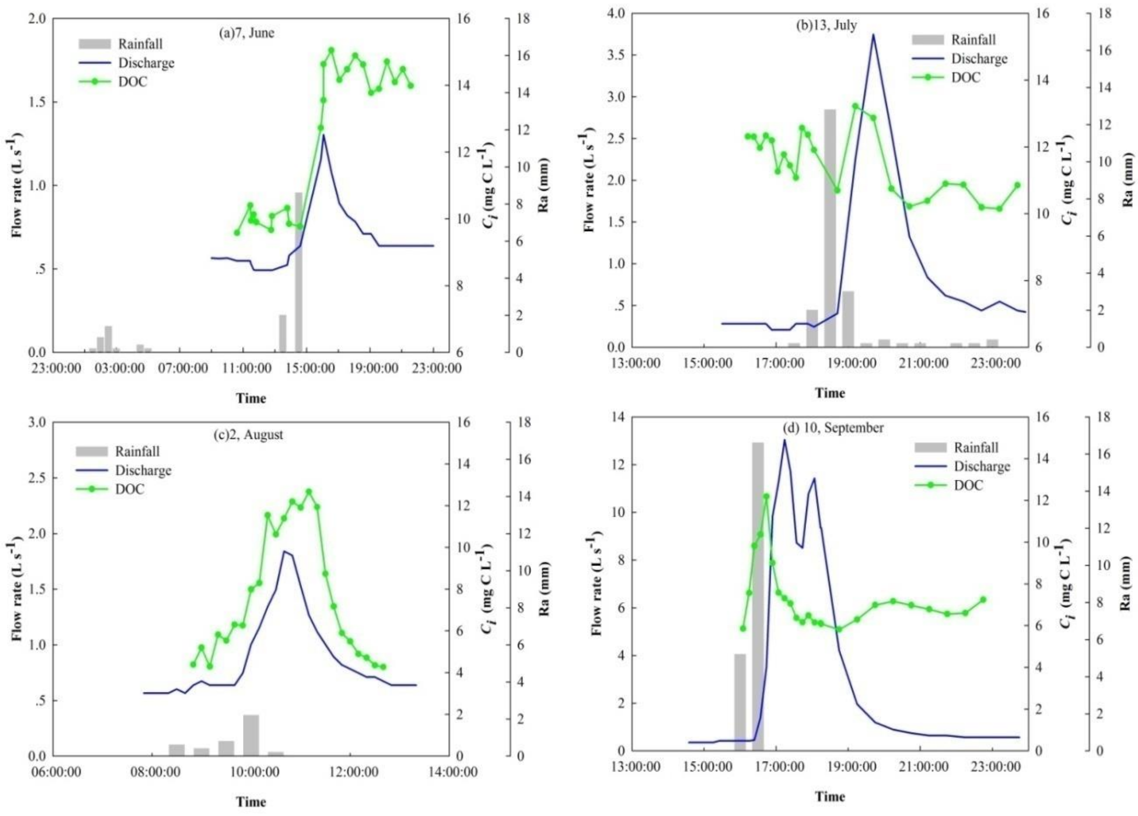
Line149-151: To analyze potential relationships among DOC concentration, flux, and selected variables, Pearson's test was performed using SPSS (Statistics Package for Social Science, Version 22).

Comment 8. I think the relationship between runoff and DOC concentration could be better explained by the DOC concentration of each runoff sample and its flow rate in the corresponding sampling period.

Response: Thanks for your remind. The discharge in this manuscript is flow rate in a hydrological process. We have changed in the Line 176-179 and the Figure 5 showed the DOC concentration of each runoff sample and its flow rate in the corresponding sampling period.

Line 176-179: The relationship between flow rate and C_f for sampled rainfall events was shown in Figure 4-b. The C_f exhibited a poor relationship with flow rate, and the C_f was a more variable at low flow rate period compared to the high flow rate period, which is typically observed during consecutive rainfall events with high rainfall amount.

Figure 5



Comment 9. This part is the interpretation or analysis of the above results, and it should be included in the section of discussion with the citation.

Response: Thanks for your suggestions. This part has been rewritten and moved to discussion section Line 250-255.

Line250-255： 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).

Comment 10. What is the difference between DOC export and DOC flux? DOC export and flux were mixed in several parts of the paper affecting readers' understanding of the study. Please explain the specific meaning of DOC flux/export.

Response: Thanks for your suggestions. In this study, *Flux* emphasize the amount of DOC loaded by a rainfall event and DOC export mean a transport process occurs in a hydrological process from a catchment. Line 136-137 has added the specific meaning of *Flux*.

Line 136-137: *Flux* (kg km^{-2}) is the quantity of DOC driven by a rainfall event for in the study region; and, *s* is the catchment area (km^2).

Comment 11. Substitute "uses" with "used". As shown in figure 2-b, the DOC concentration looked like the average DOC concentration daily or per rainfall event, rather than the results of each collected runoff samples. This figure did not show the high-frequency monitoring in your study.

Response: Thanks for your suggestions. Figure 2-b showed the event-driven DOC concentration during the monitoring period. However, the high-frequency monitoring mean the runoff samples collected in a hydrological process in this manuscript, details showed in method part in Line 102-104:

Line 102-104: High-frequency monitoring was carried out in a rainfall event based hydrological process, thus the ISCO was set to acquire samples every 10 min from the first 12 runoff samples and another 12 were sampled every 30 min.

The "uses" revised to "used" in Line 226-228:

Line 226-228: In this study, we used an in-situ auto- and high-frequency monitoring method to observe temporal changes in hydrological and DOC concentration for an event-based sampling period during the concentrated rainfall season (June-September, 2016) (Figure 2-b).

Comment 12. Is the result of the greater DOC flux with a large discharge obtained from your study? If not, it is better not to compare the result about DOC flux in previous studies with the result of DOC concentration in your study.

Response: Thanks for your suggestions. In line 230-245, these words describe the monthly DOC flux showed no linear relationship with discharge amount and discussed the potential reason. In line 272-276, these words discussed the event-driven DOC flux during the monitoring period. Details showed as following:

Line 230-245: Monthly DOC fluxes were not clearly correlated with discharge amount. The flow-weighted DOC concentrations decreased during the experimental period, which differed from the greater DOC flux with a large discharge (Chen et al., 2012; Cooper et al., 2007). Furthermore, the monthly DOC fluxes were negatively correlated with the discharge amount from June to August 2016. The DOC concentration was higher in June and decreased in August. This was reasonable because the accumulated soil organic carbon can be flushed by runoff in early rainfall period, and the DOC concentration may be diluted by increased runoff (Blaen et al., 2017; Chen et al., 2012). In addition, in combination with the increased discharge amount, the decreased concentration led to a decrease in monthly DOC flux from June to August. This could be explained by the relative changes in DOC concentrations being higher than changes in monthly discharge, indicating that the decreased concentration may outweigh the effect of increased discharge. However, the exception occurred in September, while increased DOC flux over the other three months was mainly due to a smaller increase in DOC concentration. These results were also probably associated with rainfall amount, land cover and runoff flow path (Laudon et al., 2004; Soulsby et al., 2003). For example, crops planted in the check-dam field were harvested, and the ratio of rainfall to runoff increased in September. The soil soluble organic carbon is more likely to leach through macropores from check-dam farmland into runoff, which further increased the DOC concentration in runoff. Thus, it led to a slight increase in DOC flux in September. Therefore, it could be inferred from these results that DOC flux may depend on runoff flushing capacity and flow path in a restored and check-dam catchment.

Line 261-272: 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.

Comment 13. line 266-267, line 274-277, line 300-301; and line 308-310;The above sentences are the description of the figures or tables and it is best to move those to the result section.

Response: Thanks for your suggestions. These sentences have 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 SMC7 and SMC14.

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 14. Why do you take the 20 mm rainfall amount as the break point to do the linear regression analysis respectively?

Response: Thanks for your suggestions. We have added a finding conducted by Yang and details show in the following:

Line 156-159: 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 15. line 288; The subtitle is too broad and general. Rainfall, one of the most important factors affecting DOC concentration, has been mentioned in 4.1, but not been fully discussed.

Response: Thanks for your suggestions. The subtitle has changed into "4.2 Potential Factors Influence on DOC Export". We have added some information in this discussion part and details show in the following:

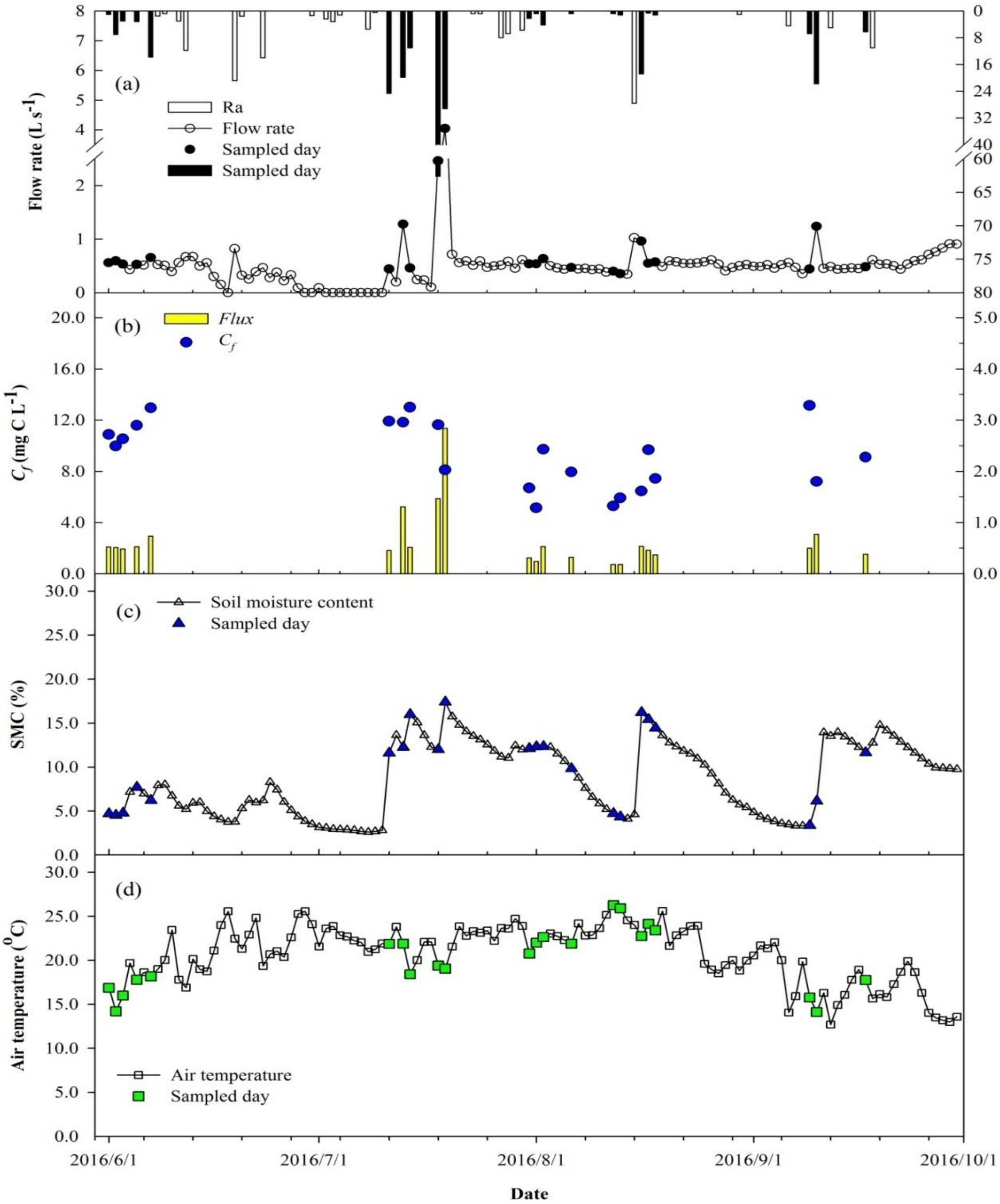
Line282-314: The infrequent and amount of violent rainfall events strongly influence the runoff discharges and soil moisture, which in turn impact on DOC during or later export from a catchment. In this study, temporal variations of rainfall, air temperature and soil moisture content were continuously monitored throughout the study period to provide detailed information describing the antecedent and current conditions. Positively correlation between Ra, R7 and C_f suggested that the combination of the current rainfall amount and the accumulated rainfall before a current rainfall event are important. R7 may reflect the antecedent hydrological condition and Ra represent the current rainfall input into the catchment, resulting in well hydrological connectivity, and more DOC source may contribute to runoff. Therefore, C_f can by strongly influenced by Ra and R7 due to the hydrological properties of the catchment. Apart from the hydrological changes, the antecedent soil moisture also played an important role in C_f and showed an extreme significantly and negatively correlated with SMC7 and SMC14 (Table 2). The soil moisture content was continuously dried and then effectively rewetted under a specific rainfall amount, as supported by the soil moisture variations shown in Figure 2-c. These results were also consistent with Yang et al. (2018), who found that the threshold of rainfall effectively recharged into soil was 20-26 mm for grassland and forestland in LPR. Therefore, the pattern of soil moisture dry-wet cycle may affect event-driven DOC concentration, and this highlights the importance of soil moisture condition in DOC export (Figure 7). The higher DOC concentrations from June to middle July coincided with light rainfall, and thus rainfall recharge into soil moisture. This is probably attributed to inactive microbial activity, caused by the relatively lower soil moisture (Jager et al., 2009). The DOC concentration decreased with increased soil moisture content, particularly in July-18 with a total rainfall amount of 56.4 mm. On one hand, violent rainfall events may induce a higher discharge, causing a dilution effects on DOC concentration. On the other hand, the rainfall water may effectively replenish soil moisture content, and thus stimulate a higher decomposition of soil carbon under wet and higher temperature condition. Then, the relative decreased DOC concentrations were observed in a drying soil moisture condition for the next rainfall events, which may attribute to an exhaustion of DOC (Laudon et al., 2004). These findings were similar to previous studies by Tunaley et al. (2017), who reported a strong influence of dry antecedent conditions on DOC export response to rainfall event.

For event-based flux, 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.

Comment 16. Figure 2; Try to use shading or background fill to distinguish the values of sampling days instead of using different colored dots.

Response: Thanks for your suggestions. The Figure 2 has been revised as following:

Figure 2

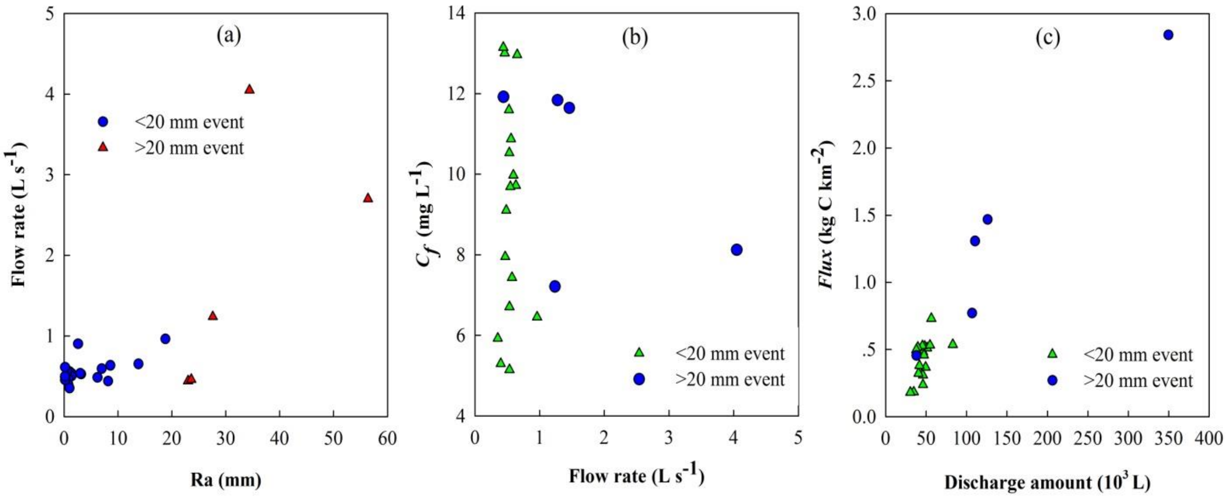


(a)
Ra
Flow rate
Sampled day
Sampled day
Flow rate (L s-1)
Ra (mm)
(b)
Flux
Cf
Cf (mg C L-1)
Flux (kg C km-2)
(c)
Soil moisture content
Sampled day
SMC (%)
(d)
Air temperature
Sampled day
Air temperature (0C)
2016/6/1
2016/7/1
2016/8/1
2016/9/1
2016/10/1
Date

Comment 17. Figure 4; Is the regression curve in the right side of figure 4 fitted according to all sampled rainfall events or according to >20 mm rainfall events? Please indicate (a) and (b) in the figure 4.

Response: 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 Figure 4 has been changed and added (a), (b), (c), respectively. The details shown in Figure 4 as following:

Figure 4



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 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^{-2} from June to September, while the event-based DOC flux ranged from 0.18 to 2.84 kg km^{-2}. 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.