---------------------RESPONSES TO THE COMMENTS---------------------

We would like to thank David Dunkerley for reviewing and commenting on our paper. We find this discussion very interesting and feel that it will enrich the final version of the paper. You will find your comments in **black**, while our responses are given in **blue** and any citation how we suggest to revise the text in the revised manuscript in **red**.

Reviewer #1:

This paper analyses runoff and soil loss data collected from several experimental plots, with data covering about a decade of observations under natural rainfall. I would first commend the authors for having adopted field study under natural rainfall, rather than the generally inappropriate reliance on "rainfall" simulation (which typically uses unrealistic, fixed, high intensities - often with little or no attempt at offering a reasoned basis for this, and typically neglecting intensity profile altogether). I think that observations made under natural rainfall are arguably far more informative and valuable than "rainfall" simulation studies that neglect the kinds of issues that are discussed in the current manuscript.

Response: Thank you for the nice comments on the significance of this study. We took them all into account in detail and respond to each below:

The use of four classes of intra-event rainfall pattern (advanced, intermediate, delayed, and uniform) is not unusual, and does provide some basis for identifying and categorising the intra-event rainfall intensity variation. However, this classification provides no indication of what the actual intensities during an event were. Indeed, it is a limitation of the current manuscript that remarkably little is actually said about the rainfall intensities, beyond reporting of the mean event intensity (I presume) for the advanced, delayed, etc. (e.g. lines 234-236). I think that it would have been helpful and appropriate for the paper to report additional detail concerning intensity - perhaps using measures like I5, I15, I30, I60, and so on. In the absence of this, we cannot really understand whether, for instance, the 'advanced' event type had different peak intensities than the other classes, and for how long those peak intensities might have lasted. We cannot see whether there was more intensity variation in advanced than in delayed, for instance, and it is well-known that short-term intensity peaks can exert critical influences on soil erosion (e.g. see for instance Dunkerley, D. L. (2019). Rainfall intensity bursts and the erosion of soils: an analysis highlighting the need for high temporal resolution rainfall data for research under current and future climates. Earth Surf. Dynam., 7(2), 345-360. doi:10.5194/esurf-7-345-2019).

Response: Thank you for the insightful suggestions. We agree to provide more information about intensities during an event. As suggested by the reviewer, short-term intensity peaks can exert critical influences on soil erosion. It is well-known that the maximum 30-min intensity of rainfall events (I30) had a significantly positive relationship with the soil erosion amount. In order to explore the peak intensity differences among the four patterns, I30 and accumulative rainfall percent for each 1/3 period were provided in Table 1. As shown in Table 1, the I30 of advanced patterns was more than the other patterns. The results were the main reason for the highest soil loss amount in advanced patterns.

Suggested revision in the text:

Table 1

Rainfall eigenvalues of four intra-event rainfall patterns (IRP). D, P, and I_{30} refer to rainfall duration, depth and maximum rainfall intensity in 30 min.

RIP	Sample size	Rainfall percent for each 1/3 period (%)			D (min)			P (mm)			I_{30} (mm h^{-1})		
		0~1/3	1/3~2/3	2/3~1	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
Advanced	109	74	15	11	27	4319	732	4.6	130.9	23.2	1.0	45.3	8.8
Intermediate	48	22	64	12	22	2972	978	7.1	72.1	26.2	0.9	22.9	6.0
Delayed	57	11	10	79	100	6191	1409	8.5	129.3	30.8	1.0	51.2	6.1
Uniform	12	33	36	31	426	2460	1362	11.7	43.5	21.4	1.0	5.7	2.9

I would like to have seen in the paper more information on rainfall continuity or intermittency also, as breaks in rainfall can be critical in allowing overland flow to slow and for soil to be re-deposited, for ephemeral surface ponding to dissipate, for soil infiltrability to partially recover, and so on. Much is known about all of this, and could have been considered in the manuscript. Many rainfall events reported in the manuscript have durations of more than 24 hours, and up to 48 hours. Was rainfall actually continuous through these long durations, or were there breaks (cessations) in rainfall? The authors might also say something about when the rain occurred, especially for the 'advanced' type. These might for instance have been late afternoon convective events, whilst the 'delayed' type might have been long, overnight falls. The timing, diurnal or nocturnal, would influence evaporation rates, especially during any temporary breaks in rainfall. This is too often ignored when rainfall data are reported simply in terms of event amounts and intensities.

Response: Thank you for the valuable suggestion. The discussion on rainfall intermittency contributed to understand the underlying mechanisms of different types of intra-event variation on surface-subsurface flow and soil loss. As suggested by the reviewer, we have added the discussion on the effect of rain intermittency on runoff generation and soil erosion under different intra-event rainfall patterns. We revised the text accordingly as follows:

Suggested revision in the text: The characteristic intermittency of rainfall includes temporary cessations (hiatuses), as well as periods of very low intensity within more intense events (Dunkerley, 2018; 2021). For instance, Figure 3 clearly shows that there is ubiquitous intermittency in most natural rainfall events, especially for long-duration rainfall events. The advanced pattern events might have been late afternoon convective events. Intense rainfall intensity was concentrated in the early period, while intermittency often occurs in the later periods (Figure 3). The intense intensity in the advanced pattern tended to induce strong runoff scour in the early periods, which greatly contributed to the development of concentrated flow and produced more intense soil erosion. In addition, early intense rainfall may also induce more splash erosion, which also provides abundant loose soil particles and thus leads to greater sediment production capacity. Conversely, the delayed pattern might have been overnight falls with long time. Most of rainfall interval occurred in the early and middle stages (Figure 3), and therefore the apparent infiltration rate expands, which greatly increased the time to first runoff and reduced surface runoff and soil erosion in the early stages. In addition, the subsurface flow was increased due to the increase of infiltration rate and intense rainfall intensity in later periods (Section 4.1).

Dunkerley, D., 2018. How is overland flow produced under intermittent rain? An analysis using plot-scale rainfall simulation on dryland soils. Journal of Hydrology, 556, 119–130. https://doi.org/10.1016/j.jhydrol.2017.11.003

Dunkerley, D., 2021. Intermittency of rainfall at sub-daily timescales: New quantitative indices based on the number, duration, and sequencing of interruptions to rainfall. Atmospheric Research, 253, 105475. https://doi.org/10.1016/j.atmosres.2021.105475

I was not entirely convinced that simply classifying rainfall events as 'advanced', 'delayed', etc. is sufficient. I think that the authors recognised this too. Clearly, the depth and intensity of the events differed widely, and this is where measures such as I30 or a related index might have been useful. In my own experimental studies, designed primarily to understand how intensity profile affects infiltration and runoff, all events, regardless of intensity profile, had the same depth, duration, and average intensity. An example is Dunkerley, D. (2012). Effects of rainfall intensity fluctuations on infiltration and runoff: rainfall simulation on dryland soils, Fowlers Gap, Australia. Hydrological Processes, 26(15), 2211-2224. doi:10.1002/hyp.8317. In that work, all events lasted 90 minutes and delivered 15 mm of rainfall at an average rainfall rate of 10 mm h^{-1}. This ability to hold depth and duration constant experimentally isolates, at least to some extent, the intensity profile itself as the factor than could account for differences in plot infiltration and runoff. But this is not possible to do when using natural rainfall. Therefore, event durations were different among the intensity profiles analysed by the authors of the present manuscript. Were the 'advanced' events primarily different in their effects on the soil plots from the 'delayed' events in terms of their intensity profile, or their duration, or their peak intensity, or the duration of intensity exceeding, say, 10 mm h^{-1}, or some other factor or factors? I think that the present manuscript leaves this unresolved. Perhaps issues of this kind could be addressed in future work by the authors. I well understand that not all questions can be addressed in a single manuscript of manageable length. It is clear from Figure 3 for instance that the 'advanced' events are much more variable in their intensity profiles than any of the other classes. The spread of event characteristics declines in the sequence advanced > delayed > intermediate > uniform. This suggests, for instance, that it might be advantageous to consider some sub-categories within at least the 'advanced' class (and perhaps also in the 'delayed'). A suitable measure might be something like 'time to peak intensity', say. It is evident from Figure 3 that some 'advanced' events are more advanced than others (i.e., that their rainfall arrives much earlier). This might be worth considering in future work.

Response: Thank you for the valuable suggestion. Rainfall simulation is a widely used research tool with the advantage of controlling single-factor variables. It provides control and facilitates the complex task of building an understanding of landsurface processes from field or laboratory experiments. Dunkerley (2012) simulated fourteen rainfall events each involved more than 5000 changes of intensity and included multipeak events with a 25 mm h^{-1} peak of intensity early in the event or late in the event and an event that included a temporary cessation of rain. The depth and mean intensity of all rainfall were 15 mm and 10 mm h^{-1}, respectively. The results demonstrated that event profile (peak intensity in which period) exerted an important effect on infiltration and runoff. However, there is a discrepancy between simulated rainfall and natural rainfall conditions. Rainfall event profile simulation experiments may not adequately capture the complexity of natural rainfall processes, and the simulation rainfall derived results need to be verified by more field natural rainfall experiments.

Rainfall intensity profiles have an extremely important and complex influences on infiltration, runoff generation, soil erosion and related landsurface processes (Dunkerley, 2021). As the reviewer said, the effects and its underlying mechanism of intra-event rainfall pattern on runoff and soil erosion were addressed difficulty in a single manuscript of manageable length. This also maked a bloated and unfocused paper. We are very grateful for the valuable comments given by the reviewer, which have given us a new perspective to analyze in depth the mechanisms of intra-event rainfall variations on soil erosion. In the future work, a series of indicators were proposed to describe the features of rainfall intensity fluctuation. For example, the fraction of duration in low-intensity zone (intermittency), the fraction of rainfall amount in high-intensity zone, the relative amplitude of rainfall intensity, and the relative number of rainfall peaks, etc. The effects of rainfall intensity fluctuation on surface-subsurface flow and soil loss are quantified.

The authors also neglect, as is often the case in such studies, the time sequence of rainfall events. This sequence influences the critical antecedent wetness (or dryness) of the plot soils prior to the start of an event. Events that begin soon after a prior event, with soils that are already partially wetted-up, are likely to have infiltration and runoff characteristics that are different to those seen when an event begins after weeks without rain, say. The literature is full of findings on such effects, and they really should not be ignored. In my own experimental work, referred to above, each experiment was made on a fresh runoff plot, and none had received any rain for some weeks, such that all plots could be regarded as having the same initial condition - 'dry'. So I would speculate that an 'advanced' event soon after a prior event would show very different runoff behavior than one on dry soil, say. And it makes limited sense to compare what happens in an 'advanced' event on wet soil with what happens on a 'delayed' event on dry soil - because it is not only the class of event that is different, but the antecedent soil wetness. The two effects are then confounded in any statistical analysis. Clearly this cannot be controlled for in work under natural rainfall, but nevertheless, antecedent conditions and their influence have to be borne in mind, and their possible effect analysed as well as can be managed. One could, perhaps, analyse as a test case only rainfall events that occurred after at least 5 days without rain, or some such criterion.

Response: We totally agree with your suggestion. The significant and complex role of soil moisture content on soil hydrology and erosion processes is recognized by many studies. Soil under different antecedent wetness or dryness had different hydrology and erosion response.

The antecedent soil moisture was not discussed in this paper for the following reasons. Firstly, unlike simulated rainfall, the antecedent soil moisture before each runoff event cannot be consistent under field observations. This is also a major feature of runoff and sediment analysis from natural rainfall events. Moreover, due to high spatiotemporal variation of soil moisture, antecedent soil moisture had not been mainly considered as a single factor during the most studies about the impacts of natural rainfall patterns of water erosion (Wei et al., 2007; Fang et al., 2012; Liu et al., 2016; Feng et al., 2020; Yang et al., 2022; Liang et al., 2023). Thirdly, rainfall events that occurred after at least 5 days without rain were selected to analyze. This is a good way to solve the error brought by the difference of antecedent soil moisture under the same land use type. However, surface cover on bare soil had a great influence on soil moisture redistribution under natural rainfall events. In this paper, soil water distribution in the three plots was significantly different under the same rainfall conditions. Therefore, even based on the above criteria, it may not be possible to obtain the runoff events with relatively consistent antecedent soil moisture.

It is an important solution to improving the credibility of natural rainfall experiment by increasing the sample numbers (rainfall events) as much as possible. This also reflects the high value of long-term in situ field observations of natural rainfall. In other words, with a large number of samples (rainfall events), the importance of intra-event rainfall variability in soil erosion is better demonstrated. In this paper, 262 rainfall events were obtained by the method of long-term in situ observation (11 consecutive years). Although it cannot explain the role of antecedent soil moisture in runoff generation and sediment loss, it truly reflects the influence of natural rainfall patterns on water erosion. The results showed that natural rainfall patterns have significant effects on surface-subsurface flow and soil loss. It fully indicates that the results are credible.

The combined effects of natural rainfall patterns and antecedent soil moisture on runoff generation and soil loss were the focus of our future research. To obtain the temporal dynamics of soil moisture, automatic monitoring instruments were installed along the slope. The influences of rainfall classification on water erosion under different antecedent soil moisture were detailly investigated and discussed.

The manuscript is generally clear and easy to read. There are minor errors that could be corrected easily. The authors variously report that they analysed 226 rainfall events (line 225) or 262 events (lines 321, 504). I am not sure which number is correct. I doubt that the plot walls were actually 100 cm (1 m) tall - as stated in line 148. I cannot see how one can obtain 1 min rainfall data (line 105) from a standard tipping-bucket rain gauge. During many clock minutes, a bucket would simply be filling progressively, and might finally tip during a minute that actually delivered very little rain. This just requires some care in data processing. I generally don't see much validity in expressing tipping-bucket gauge data at any finer accumulation duration than 5 - 15 minutes, depending on the rainfall intensity.

Response: Sorry for the minor errors. Thank you so much for being so precise.

During the observation period, 226 natural rainfall events that generated runoff and soil erosion were recorded.

As shown in the following figure, in order to isolate hydrological disturbances from adjacent plots, concrete walls 100 cm deep were constructed around the runoff plots. Two runoff storage containers were set in the bottom of each plot to measure the surface and subsurface flow. The outlet of the subsurface flow was set at a soil depth of 60 cm at the bottom of the Bs layer.

Rainfall amount was measured with an accuracy of 0.2 mm using a tipping bucket rain gauge with a data logger. All rainfall data obtain methods have been modified in the revision text.

Suggested revision in the text:

The mistakes about natural rainfall events have corrected in lines 22, 321 and 504. In lines 181-182, natural rainfall depth was measured by a tipping bucket rain gauge with a data logger (RG3-M, Onset Computer Corp., Bourne, MA, USA). The accuracy of rainfall data logging is recorded with the resolution of 0.2 mm (the rainfall amount under one tip).

In line 65, perhaps find a better expression than 'inter-fluctuations'. In line 166, avoid using '5-cm'. The international SI metric system requires that only a space can come between a quantity (in this case, 5) and the units of measurement (in this case, cm). The correct form is therefore "5 cm". In lines 171-172, I did not understand what the 5 measurements were for. Was this to measure the depth of water in a collecting vessel? In line 218 I think that the word 'and' is superfluous in the expression "the and runoff plot".

Response: We agree to correct it in the text. Thank you so much for being so precise.

Suggested revision in the text:

In line 65, we have replaced "inter-fluctuations in rainfall characteristics" with "rainfall intensity fluctuation".

In line 166, "5-cm" has been changed to "5 cm".

In lines 171-172, a ruler was used to measure the water levels repeating 5 times in each runoff container after each rainfall event as a means of calculating runoff volume.

In line 218, "the and runoff plot" has been changed to "the runoff plot".

Among the 'key words', I would suggest adding something like 'intensity profile' or 'storm type' or 'storm pattern' (the terminology is currently not settled).

Response: We agree to add the key words. Thank you so much for being so precise.

Suggested revision in the text: "Rainfall intensity fluctuation" and "natural rainfall " have been replaced with "rainfall intensity profile" and "storm pattern", respectively.

As the foregoing will have suggested, there is a considerable body of literature that could have been cited (e.g. on the time-sequence of rain events and the effect this has on antecedent wetness and hence on plot behavior). The authors might find the following paper to be of interest, for example, as it addresses the significance of intensity profile, though I do not suggest that this needs to be cited, as I am among the authors. Liang, Y., Gao, G., Liu, J., Dunkerley, D., & Fu, B. (2023). Runoff and soil loss responses of restoration vegetation under natural rainfall patterns in the Loess Plateau of China: The role of rainfall intensity fluctuation. CATENA, 225, 107013. doi:https://doi.org/10.1016/j.catena.2023.107013

Response: We are thankful for providing the latest research about the effects of natural rainfall patterns on water erosion. As stated by the reviewers, a number of scholars have examined the impact of the time-sequence of rain events on runoff and soil loss. For example, Mohamadi & Kavian (2015), Wang et al. (2017), Liu et al. (2022) and Liang et al. (2023) explored that the roles of natural rainfall pattern on surface runoff and soil loss. The erosive rainfall events were grouped into different rainfall patterns based on the occurrence time of the most intense rainfall, including the early-peak, center-peak, late-peak, and uniform patterns. The above studies shed light on the crucial role of natural rainfall pattern in yielding surface runoff and soil loss, and highlighted that which pattern may be responsible for triggering serious soil erosion.

However, little attention is given to the response of subsurface flow generation to natural rainfall patterns. Subsurface flow is a key component of rainfall runoff, and its output is even higher than that of surface runoff in the rainfall regime with long duration and high depth. The formation of subsurface flow significantly altered soil moisture redistribution, soil hydrology and slope erosion processes. Therefore, in this study, long-term in situ field observations of surface-subsurface flow and soil loss characteristics under natural rainfall events were conducted in three surface cover plots (bare land, litter and grass cover). This is the major novelty and advancement of this study. The results contributed to a better understanding of soil hydrological processes and erosion mechanisms caused by natural rainfall.

Suggested revision in the text: The literature (Liang et al., 2023) have been cited in the revision manuscript.

References

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