Comment from RC1 and the replies

To reviewer:

Thanks for your important comments for this work, your good comments help us improve the quality of this manuscript a lot, such as the clear explanation of the contribution of last figure, high soil loss in channel bed in snow-melting season. We made a point-to-point replies for your comments.

Comment 1: The title and objective of this study did not show the key important finding of this study, I suggest the author to make the clear progress in these key parts including the hydromechanical properties.

Replies: Done.

Firstly, the title in the previous manuscript does seem to too regular and does not show the important finding of this work. This main contribution of this work, as the comment 2, lies in that the soil loss on bank closely relate to the role of suction stress and the soil loss in channel bed relate to the storied water. Besides, the soil water storage does not equal to the event rainfall amount, but partially from the initial soil water. This finding sufficiently illustrates that the antecedent precipitation or initial soil moisture within the soil plays an important role in soil loss on both bank slope and channel bed. Therefore, we decided to revise the previous title into "**Understanding soil loss in mollisol permanent gully head cuts by hydrological and hydro-mechanical response**". The revised title could reflect the clear progress, including the soil loss, hydromechanical properties, and water storage.

Secondly, the objective of this work (as written in the abstract, final paragraph in the Introduction part and the Discussion part) should strengthen the important finding of this study. Therefore, we revised the three parts following your suggestion. In the revised manuscript, the three parts were revised as:

Abstract: During permanent gully development, soil losses on steep slope and in channel bed are typically driven by the hydromechanical response and water storage within the soil mass, while such knowledge have been neglected in previous studies of gully erosion in the mollisol region of Northeast China. In this study, erosion intensities during the 111 d of the rainy season and 97 d of the snow melting season were analyzed with respect to soil water storage and drainage capacity, soil suction stress, supported by the monitoring results of soil moisture, temperature, and precipitation and experimental analysis of soil hydromechanical properties. Under the same confining stress, the mollisols in the interrupted head cut of Gully No. II increased more rapidly and dissipated pore water pressure more than at the uninterrupted head cut of Gully No I. The combination of the soil water characteristic curve and the hydraulic conductivity function indicates that the mollisols of Gully No. II had a lower air entry pressure and higher saturated hydraulic conductivity during the wetting and drying cycles than Gully No. I. The head cut area of Gully No. II exhibited rapid response of water infiltration and drainage, and high soil water storage capacity. The absolute suction stresses within the mollisols of Gully No. II was lower than that in Gully No. I, which could lead to high erosion per unit of steep slope area. Importantly, gravitational mass wasting on steep slopes is closely related to soil suction stress and we observed a correlation between erosion per unit gully bed area and the soil water storage. Therefore, it is more important to predict the soil loss in permanent gully from both soil water storage and the hydromechanical response of soil mass, other than sole rainfall amount.

Final paragraph in the Introduction part: Soil loss from gravitational mass wasting on the steep slope of a permanent gully is poorly understood in the MEC. To date, relatively few studies have addressed its relationship with the hydrological and hydro-mechanical response of the soil mass. This work has focused on how the monitored soil water change and the suction stress affect soil loss during the rainy and melting seasons in the head cuts of two permanent gullies, where one head cut experiences no human activity, whereas the other does. Soil loss in the head cut area during the rainy and melting seasons was observed. The differences in the physical properties of the mollisols, such as pore water pressure dissipation at a given confining stress, the soil water characteristic curve (SWCC), and the hydraulic conductivity function (HCF), were compared. The soil loss per unit area on the steep slope and gully bed was analyzed for the soil water storage, drainage and the soil suction stress, respectively. The objective of this study mainly exhibits the relationship between soil loss intensity on steep slope and hydro-mechanical response of the soil mass, and the intensity in channel bed with water storage.

The discussion part: Commonly, the gully bed erosion rates mainly depend on runoff intensity, and some study found that the hydraulics of runoff in the rainy season was significantly higher than the snow melting runoff. However, some studies also proved that gully head may retreat faster in the snow-melting season than in the summer (Wu et al., 2008; Hu et al., 2009). In fact, the accumulated snowfall depth during the monitoring duration in this work was high up to 49.6 mm, which was far more than the average snow depth of 30 mm. Besides, the snowfall was melted all during 3 to 10 May 2023. Therefore, heavy snowfall during the winter 2022 and early spring 2023 and the intensive melting may result in the high soil moisture, intensive runoff to cause strong bed erosion.

Comment 2: Figure 11 (last figure) is the key finding and main contribution in the study domain of gully erosion, as it clearly clarifies the role of suction stress of storied water on soil loss from slope and gully bed respectively. In predicting the soil loss, the soil water storage (unit: mm) couldn't equal to the event rainfall amount, but partially from the initial soil water. Therefore, I suggest the authors strength the application of the results of figure 11, or give some clear explanations.

Replies: Good suggestion here.

We should give a clear explanation to the finding in fig. 11.

In the final paragraph of Discussion. We added a paragraph to give clear explanation:

The added part is: The result in Figs. 11c and 11d is a key finding and main contribution in the study domain of gully erosion, as it clearly clarifies the role of suction stress of storied water on soil loss from slope and gully bed respectively. It also tells the truth that the soil water storage couldn't equal to the event rainfall amount, but partially from the initial soil water. In other words, the effect of antecedent precipitation would be assessed in predicting soil loss as it closely relates to the soil water and generate indirect influence on the runoff generation and intensity. Importantly, the ideology of this work adopts the theory frame that the soil loss at the steep slope occur by the mechanism of bank slope stability and the loss in the gully bed occur on condition that the balance between the shear force from runoff water to soil erodibility. Therefore, it is more important to predict the soil loss in permanent gully from both soil water storage and the hydromechanical response of soil mass, other than sole rainfall amount.

Comment 3: Some figures are not clearly show the results: Fig 2, gully No II, the widths decreased from 2 to 3, which was confusion to me.
Replies: It's true.

Fig. 1b and 1c clearly shows the planform of the gully area. The shape of the gully area is odd-looking as the head area of gully No. II suffer from excavator interruption. However, the planform of the gully No. II common-looking.

Comment 4: Figure 3, normally the gully bed erosion rates was mainly caused by the runoff scouring, and many previous studies proved that the hydraulics of runoff in the rainy season significant higher than the snow melting runoff. So how do you explain the extremely high erosion rates of gully bed 1 in snowmelt season?

Replies: Good comments here.

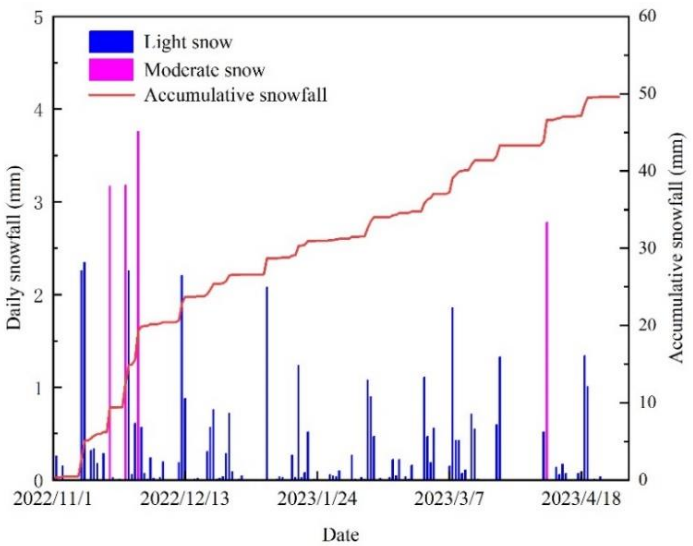
The thicker snowfall depth over average values and longer snow-melting resulted in the high soil loss.

In this work, we claimed that long-term saturation during the snowmelt season provides sufficient water infiltration and low suction stress. Therefore, the highest erosion per unit area occurred in the snowmelt season, but not in the rainy season (Fig. 11c).

However, the extremely high erosion rates of gully bed No. I was found in snowmelt season. This finding can be explained by the heavy snow events with accumulative snowfall depth up to 49.6 mm in the winter of 2022 and the early spring of 2023, which was far more than the average snow depth of 30 mm. The thicker snow depth over average depth means that more soil loss would be eroded, which can be exemplified by the results of Tang et al. (2021). Tang et al. (2021) developed an empirically-based formula to estimate the soil loss during snow melting season:

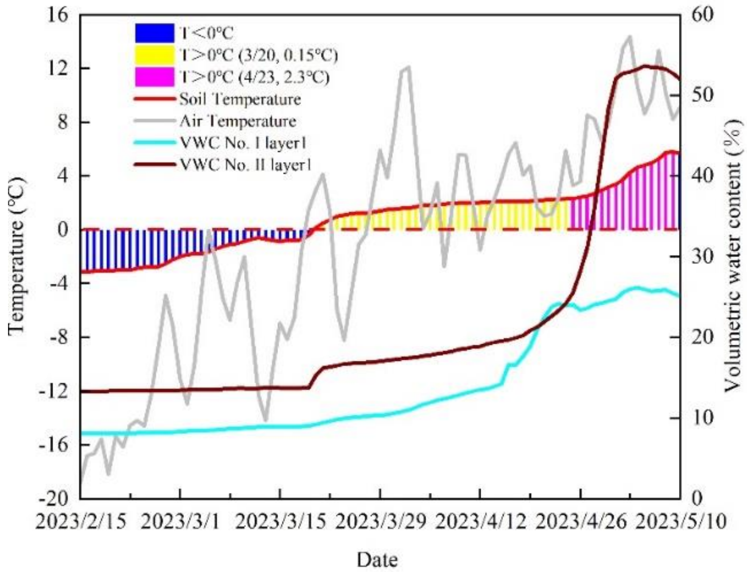
$$V=0.102\times SN^{1.104}\times SR\times A^{0.9}\times T^{3.0}\times BD$$

where V is the soil loss, SN is snow depth, SR is a dimensionless snow redistribution factor, A is the upslope contributing area, BD is soil bulk density. At given permeant gully, high soil loss must need strong snowfall. As the snowfall depth was up to 49.6 mm in the winter of 2022 and the early spring of 2023, which was far more than the average snow depth of 30 mm.



The snowfall distribution during the winter 2022 and the early spring 2023

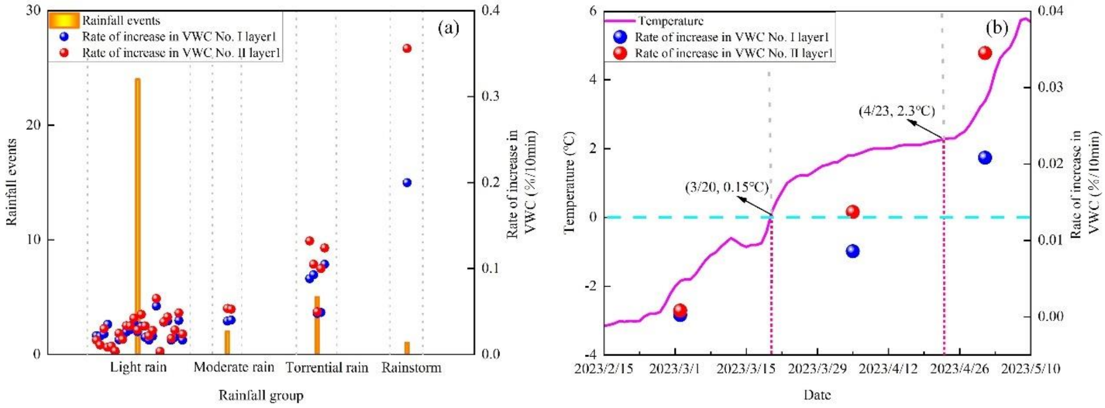
Another reason for the high extremely high erosion rates of gully bed No. I in snowmelt season lies in that the longer duration of snow-melting than the storm duration (as shown in fig. 7). The intensive snow melting mainly occurred during 3 and 10 May 2023 (about 7 days). However, the duration of storm was far less than the time-lasting of snow-melt.



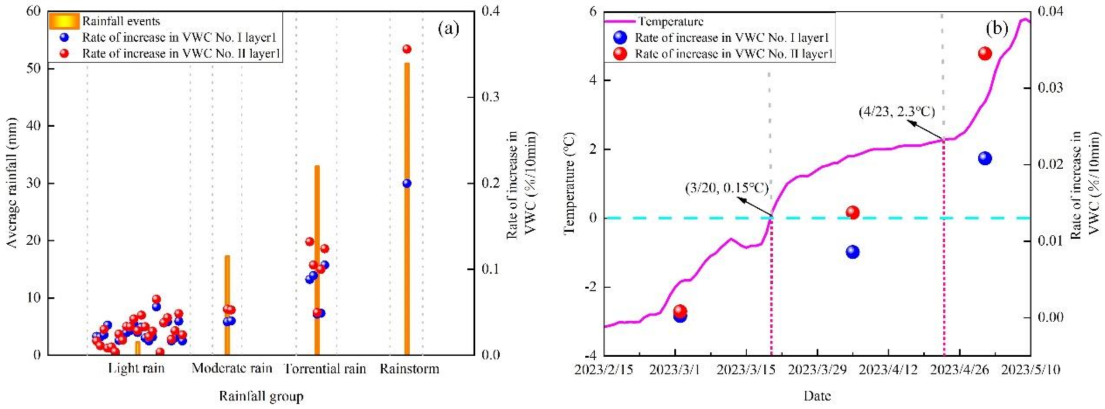
The snow-melting duration in the early spring 2023

In the revised manuscript, we added a paragraph (Discussion part) to explain this finding: Commonly, the gully bed erosion rates mainly depend on runoff intensity, and some study found that the hydraulics of runoff in the rainy season was significantly higher than the snow melting runoff. However, some studies also proved that gully head may retreat faster in the snow-melting season than in the summer (Wu et al., 2008; Hu et al., 2009). In fact, the accumulated snowfall depth during the monitoring duration in this work was high up to 49.6 mm, which was far more than the average snow depth of 30 mm. Besides, the snowfall was melted all during 3 to 10 May 2023. Therefore, heavy snowfall during the winter 2022 and early spring 2023 and the intensive melting may result in the high soil moisture, intensive runoff to cause strong bed erosion.

Comment 5: Fig 8.a, the bar of “rainy events” is not clear, and in my opinion, showing the average rainfall of each rainfall grade can better reflect the impact on VWC.
Replies: Done.
Thanks for your patience and recommendations here. It greatly improves the quality of our text. As you say, showing the average rainfall of each rainfall grade truly can better reflect the impact on VWC, So we made the change as you suggested. Thereinto, The average rainfall during light rain events is 2.24 mm, average rainfall during moderate rain events is 17.22 mm, the average rainfall during torrential rain events is 32.91 mm, the average rainfall during rainstorm events is 50.87 mm. We've made changes to the Fig 8 (a).



The previous fig. 8



The revised fig. 8

Comment 6: Some important references need be cited, e.g. Hu Gang et al., (2007, 2009), Wu Yongqiu et al., (2008).
Replies: Sincerely thanks for your good suggestion here.

Thank you for sharing such important documents about the soil loss in the mollisol region of Northeast China.

We also find important evidences from them that the they all claimed that: it is remarkable for freeze-thaw erosion in the black soil area of NE China (Hu et al., 2009), gully heads retreated faster in the spring freeze-thaw period than in the summer (Wu et al., 2008), the erosion by freeze thawing and snowmelt accounts for a large percent (Hu et al., 2007).

In the revised manuscript, we wrote sentences (in the middle part of the third paragraph, Introduction part) to summarize their important results to support my ideology of this work, and the three documents improved the structure of this manuscript a lot.

The added sentences are "Note that some studies proved that the soil loss during snow-melting season remarkably accounts for a large percent (Hu et al., 2007 and 2009), and gully heads retreated faster than in the summer (Wu et al., 2008). Currently, the hydrological processes near the head cut and the hydromechanical response of mollisols to water infiltration in the two seasons have never been documented.

The three works are:

Hu, G., Wu, Y., Liu, B., Yu, Z., You, Z., and Zhang, Y.: Short-term gully retreat rates over rolling hill areas in black soil of Northeast China, Catena, 71, 321-329, https://doi.org/10.1016/j.catena.2007.02.004, 2007.

Hu, G., Wu, Y., Liu, B., Zhang, Y., You, Z., and Yu, Z.: The characteristics of gully erosion over rolling hilly black soil areas of Northeast China, J Geogr Sci., 19, 309-320, https:// 10.1007/s11442-009-0309-4, 2009.

Wu, Y., Zheng, Q., Zhang, Y., Liu, B., Cheng, H., and Wang, Y.: Development of gullies and sediment production in the black soil region of northeastern China, Geomorphology, 101, 683-691, https://doi.org/10.1016/j.geomorph.2008.03.008, 2008.

Tang, J., Liu, G., Xie, Y., Duan, X., Wang, D., and Zhang, S.: Ephemeral gullies caused by snowmelt: A ten-year study in northeastern China, Soil Tillage Res., 212, 105048, https://doi.org/10.1016/j.still.2021.105048, 2021.