Comment: The hydro-mechanical properties of soils were widely recognized as a major factor influencing some key sub-processes of gully erosion, but due to the difficulty of monitoring the infiltration during the gully development, especially in the field. Therefore, this study has important contribution to reveal the influences of different hydro-mechanical properties on gully erosion through a well design monitoring scheme on soil-related properties. But there are a few key questions need be explained clearer and precisely, which may strongly affect the results and conclusion of this study. I suggest major revision right now.

Replies: Thanks for your recognition for our works.

We made a throughout revision for the previous manuscript. **Please see the manuscript with marked changes and accepted changes.**

From the perspective of unsaturated soil mechanics, any soil failure results from the imbalance of the force or stress. In the research field of soil erosion, the gravitational mass movement shares the same mechanics of soil slips or landsliding while the scale of gravitational mass movement is smaller than slips and sliding, and it is difficult to monitor the interior stress status. Therefore, soil water status and the soil stress of the soil mass may give insightful knowledge about the permanent gully expansion, which is the focus of this work. In this study, we carried out a well-design monitoring scheme to obtain the soil water status and suction stress. Our results do contribute a lot to the knowledge about the physical process of permanent gully development. In the next, we will continue to extend our methods and give a clearer introduction to the gravitational soil loss in melting and rainy season.

Comment: The authors should give more details about the gully monitoring by the UAV, and the processes to calculate the variation of the gullies, and the accuracy of the monitoring methods. How you dealt with the effects of vegetation on morphological changes of gullies? I saw a lot of plants on your selected gully beds.

Replies: Done.

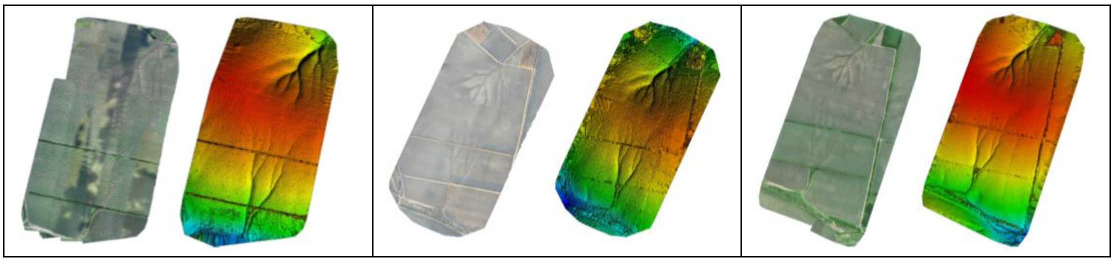
Thanks for your reminding here.

The plants are grass, not trees. If the plants are trees, it is very difficult to hanlding them by our Resisted Pix4D software.

The other two reviewers also gave me such comments about the UAV information. We should give a clear description of the UAV information and how we use software (Resisted Pix4D software) to diminish the effect of vegetation on morphological changes of gullies. In the revised manuscript, we added a new table (table 1 in the revised manuscript) to give the detailed information of the UAV and three flights. As our UAV have Real-time kinematic (RTK for abbreviation), the digital elevation models are high-resolution. Besides, we used Pix4D software to deal with the vegetation problem by generating point cloud and filtering tool.

The orthomosaic images and corresponding digital elevation models are shown as follows:

Date: 2022.06.28	Date: 2022.10.17	Date: 2023.06.21



The new table is：

Table 1. Detailed information of three UAV flights and the digital elevation models

UAV model	Flight date	Flight height (m)	DEM Accuracy (m)	Image overlap (%)
DJI Inspire 2 RTK	2022.06.28	200	0.058	80
DJI Phantom 4 RTK	2022.10.17	500	0.108	80
DJI Phantom 4 RTK	2023.06.21	150	0.042	80

Vegetation processing involved the following steps:

Step 1. We used Pix4D software to process image synthesis and the gully topography producing, which can reallocate the point cloud and filter the points of vegetation layer. As the points of vegetation layer (mainly the grass leaf) is changeable in plant height while the ground point is fixable, the vegetation layer could be filtered out and removed through the filtering tool.

Step 2. Following manual screening to ensure the removal of any residual vegetation layer point clouds, the elevation data was regenerated, yielding a processed Digital Elevation Model (DEM) for the watershed.

Step 3. The erosion mainly occurs in the slope area and the gully bed area. For sites beyond the gully area, the topography change does not consider in our works as these sites are flatten and not in the gully area. Therefore, gully edges were delineated through visual interpretation of RGB optical images, with efforts made to exclude vegetation on the banks to the greatest extent possible.

The DEM was resampled to 0.10 m using ArcGIS 10.8 software. Ground control points were employed to perform local precise registration of the drone aerial imagery within ArcGIS 10.8, thereby minimizing errors in gully delineation. These ground control points were also utilized to enhance the accuracy of three DEMs.

Comment: The authors should clarify the concept of "gully beds" and "slopes" in this manuscript, which I suggest you to marked the location of "gully beds" and "slopes" on figure 1b and c. And to me, the location of "slope" is very difficult to be determined.

Replies: Done.

We should give a clearer symbol to distinguish the gully bed and slope. In the revised manuscript, we improved the quality of figure 1 and figure 2.

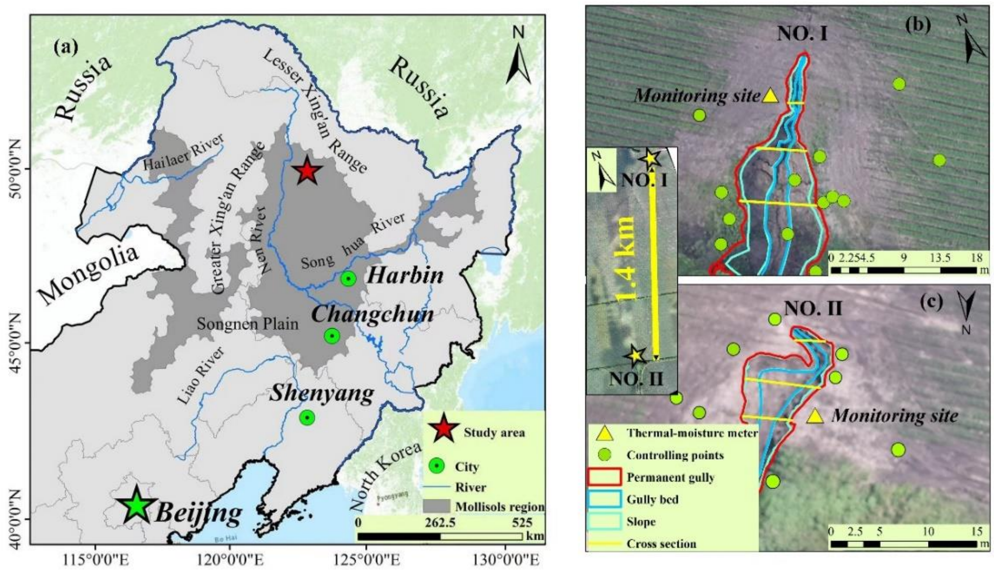


Fig. 1. Location of the two permanent gullies in the Mollisols region of northeast China. **(a)** The red star marks observation site in the study area (from ESRI). **(b)** Monitoring sites and ground controlling points at permanent gully No. I. **(c)** Monitoring sites and ground controlling points at permanent gully No. II. (background of **a** is from ESRI; areal maps of **b** and **c** are from UAV by Shoupeng Wang; the area between the blue lines mark gully bed, and the area between pink and blue lines mark the steep slope).

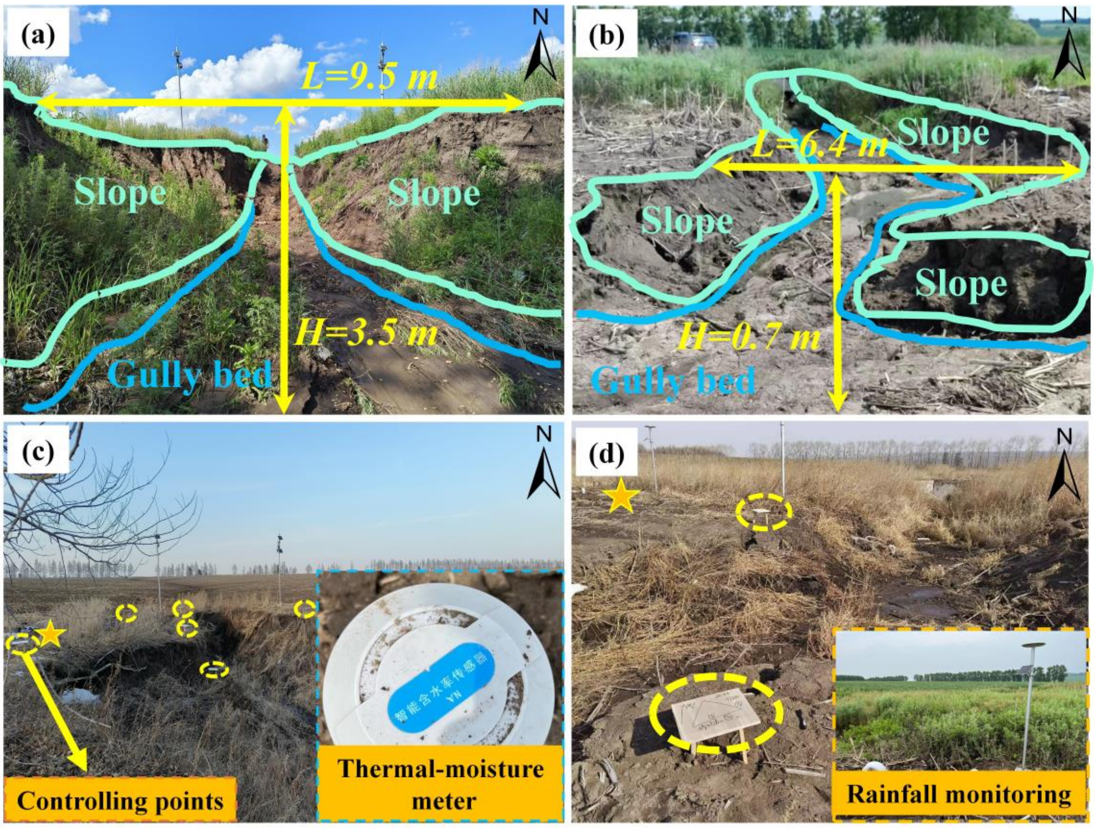


Fig. 2. A close view of the over-steepen slope and headcut of the two permanent gullies, with **(a)** cross section and upstream view of the permanent gully No. I, **(b)** cross section and downstream view of the permanent gully No. II, (**c**) ground controlling points (blue dot circles) and the soil moisture-temperature monitoring site (yellow star) at permanent gully No. I, and **(d)** ground controlling points and the soil moisture-temperature monitoring

sites at permanent gully No. II. The location of headcut of the two gullies is shown in fig. 1. The area between blue lines marks the gully bed. The area between the pink and blue lines marks the slope.

Comment: The discussion part is quite weak right now. The author should compared your results with previous studies, especially some studies related to gully piping erosion. Soil properties i.e bulk density, grain sizes and porosity have great influence on soil hydro-mechanical properties, and more easy to obtain the data. So I suggest the authors to analyze the relationship between these properties.

Replies: Done.

Maybe you are good at the pipping erosion, which is one of the most important factors causing permanent gully development. Discussion part in the previous manuscript is a little weak and the quality must be improved. In the revised manuscript, we added some sentences to mention what your good suggestions here.

Previously, we found that the research about permanent gully expansion or development mainly focus on the runoff process or topographical threshold, and neglects the role of soil stress. The gravitational mass movement, soil slips, avalanches (merely soil water-related) are closely related to the soil stress status, which is the main ideology of this work. Besides, this work used complicated and expensive method to obtain the soil hydro-mechanical properties. We nearly used 14 days to measure the wetting and drying process (The reason that such long duration lies in the fine particles of Mollisols). Then, we derived the soil-water-characteristic-curve using Hydrus 1-D (may cost me another 14 days). As you said, bulk density, grain sizes and porosity have great influence on soil hydro-mechanical properties, and easier to obtain them. However, these data must be tested by the accuracy apparatus, and could be used for soil hydro-mechanical property analysis. For example, the soil porosity, can be divided into matrix pore and macro pore. It has various class by the pore size and which pore determines the hydro-mechanical property is the greatest challenge in Unsaturated soil mechanics. The reason why we choose the two gullies lie in that the soils are undisturbed and disturbed. Such soil status would result in the differences in the hydro-mechanical properties. Therefore, we wrote some sentences in the revised manuscript to highlight this aspect.

Comment: The erosion of "slope" was correlated with suction stress is OK to me (Fig 10.c), but the "gully bed" normally considered to eroded surface runoff, and how to explain the influences by water storage need be more clear.

Replies: Done.

Erosion of gully bed positively relates to surface runoff. In a given rain event, the more surface runoff, the less the water storage. In fact, water storage and the runoff depth were approximately equal to the rainfall depth. Consequently, the erosion per unit area of the channel bed was inversely proportional to the water storage.

In the revised manuscript, figure 11c (as figure 10c in previous manuscript) sufficient prove that the low suction stress (or high soil moisture) corresponds to the high slope erosion or intensive gravitational mass movement. Figure 11d describes the stored water with the erosion. The more the water is stored in rain events, the less the runoff a catchment will produce.

In the revised manuscript, we strengthened this part in the third paragraph of Discussion.

Comment: Line 27: "gully bead"?

Replies: Sorry to make a mistake here.

It should be gully bed, not gully bead. We already revised it.

Comment: Line 49-50: "one of the most important factors in the development of permanent gullies, could be determined by the topographical threshold and volumetric retreat rate of gully headcut", the development of gullies determined by three main processes: headcut retreat, deepen and widen.

Replies: Thanks for your exact definition of permanent gully development.

We know that gully development derives from retreat, deepen and widen. We should write a more exact description about the gully development here.

In my opinion, gully deepen mainly relates to the concentrated runoff water. Widen refers to the gravitational mass movement from gully slope. Headcut retreat derives from the deepen process. This sentence seems to be a little redundance. So I revised it into "Permanent gullies initiate in locations where concentrated flow can erode and delivery bed sediments (Kirkby and Bracken, 2009), and expand at the over-steepen slopes when gravitational mass-wasting process occur following instant or constant water infiltration (Poesen et al., 2010; Tebebu et al., 2010). Development of permanent gullies, could be determined by the topographical threshold and volumetric retreat rate of gully headcut (Svoray et al., 2012; Guan et al., 2021; Zare et al., 2022), gully length-area-volume relationship (Li et al., 2015 and 2017), as well as their function with upstream drainage area and rainy days in different environments (Hayas et al., 2019)."

Comment: Line 56-57 "most studies on permanent gullies have primarily concentrated on the gully headcut retreat and topographic threshold conditions", this sentence did not summarized the previous studies well, I suggest that the authors emphasize the GHR processes through surface runoff processes as previous studies (contrast with runoff infiltration), and delete the topographic threshold part, which is not directly related to this study.

Replies: Done.

Thanks for your suggestion here. The same problem with the Line 49-50.

I have to say that tremendous GHR studies in the world and we should improve our knowledge about the GHR through surface runoff process.

Follow your suggestion here, we deleted line 56-57 as this sentence seems to be not useful and is not helpful for the contents of this work.

Comment: Line 114: check the total area of mollisols regions, which normally over 1,000 000 km^2.

Replies: Sorry to make a mistake here.

It should be 1,030 000 km^2. We already revised it.

Comment: Line 115: whether maize belong to grain or not?
Replies: We timely checked it.

We revised the maize into corn.

Of course, if you have more detailed description here, we would like to accept your suggestions.

Comment: Line 125-127: give some basic topographic parameters of these two gullies i.e length, widths, depths, area, volumes.
Replies: Done.

Sorry to miss your mentioned some gully information here.

In previous manuscript, we merely give the geometric of the headcut area of the two gullies. In revised manuscript, we

In the revised manuscript, we used one paragraph to describe the basic topographic parameters of the two gullies: "The observed two permanent gullies in this work are 1.4 km apart and are located on south-facing and north-facing rolling-slope respectively (Figs. 1b and 1c). The catchment area above the heacut of gully No. I is 0.22 km^2. The relative relief and the channel gradient are 25.85m and 3.3%. The catchment above the headcut of gully No. II is 0.35 km^2, and the relative relief and channel gradient are 26.1 m and 3.2%. The width of gully No. I gradually broadens while that of gully No. II becomes narrow, and the depth of gully No. I is deeper (Figs. 2a and 2b). In detail, the mean depth of the gully No. I is 3.5m while that of gully No. II is 1.23 m. The mean length and width of No. I gully are 25.3m and 8.72m, while those of gully No. II are 28.2 and 5.61 m. The gully area for No. I is 199.3 m^2 and the volume is 863.6 m^3. For gully No. II, the gully area and volume are 143.3 m^2 and 123.6 m^3."

Comment: Line 134-135: "The study area has a cold temperate continental monsoon climate with variable annual precipitations ranging from 480 mm to 512 mm, and 600 mm on average", confusion data.
Replies: Sorry to make a mistake here.

We checked the data with my teammates in the author list.

It should be "The study area has a continental monsoon climate with variable annual precipitation ranging from 347 mm to 775 mm, with 546 mm on average for the years of 1971 through 2018 (Tang et al. 2023)".

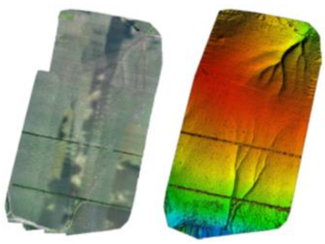
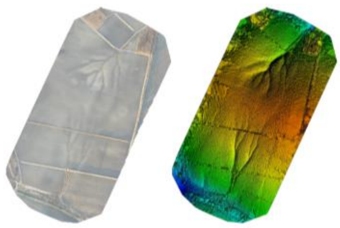
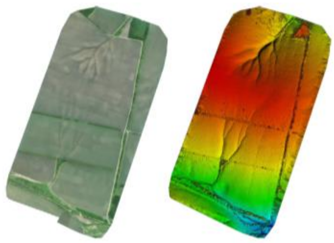
We already revised it in the revised manuscript.

Comment: The second paragraph of section 3.1: more details about the gully monitoring are required: control plates were only applied to check the accuracy of the UAV DSMs, or also as the ground control points to improve the accuracy of DSMs? Which software you used to produce the DSMs? What about the flight height and the overlaps of photos? How to reduce the influences of the vegetation in gullies.
Replies: Done.

Thanks for your reminding and another reviewer's comments about the UAV information. We added corresponding information and the strengthened this part in the revised manuscript.

The ground control points (GCPs) offer reference points enabling photogrammetry software to more accurately calibrate camera positions and orientations, as well as better align and georeference aerial images. This step is crucial for ensuring the accuracy and correct spatial referencing of the DEM, particularly in applications requiring high-precision terrain modeling. We should give a clear description of the UAV information and how we use software (Resisted Pix4D software) to diminish the effect of vegetation on morphological changes of gullies. In the revised manuscript, we added a new table (table 1 in the revised manuscript) to give the detailed information of the UAV and three flights. As our UAV have Real-time kinematic (RTK for abbreviation), the digital elevation models are high-resolution. Besides, we used Pix4D software to deal with the vegetation problem by generating point cloud and filtering tool.

The orthomosaic images and corresponding digital elevation models are shown as follows:

Date: 2022.06.28	Date: 2022.10.17	Date: 2023.06.21
		

The new table is：

Table 1. Detailed information of three UAV flights and the digital elevation models

UAV model	Flight date	Flight height (m)	DEM Accuracy (m)	Image overlap (%)
DJI Inspire 2 RTK	2022.06.28	200	0.058	80
DJI Phantom 4 RTK	2022.10.17	500	0.108	80
DJI Phantom 4 RTK	2023.06.21	150	0.042	80

Vegetation processing involved the following steps:

Step 1. We used Pix4D software to process image synthesis and the gully topography producing, which can reallocate the point cloud and filter the points of vegetation layer. As the points of vegetation layer (mainly the grass leaf) is changeable in plant height while the ground point is fixable, the vegetation layer could be filtered out and removed through the filtering tool.

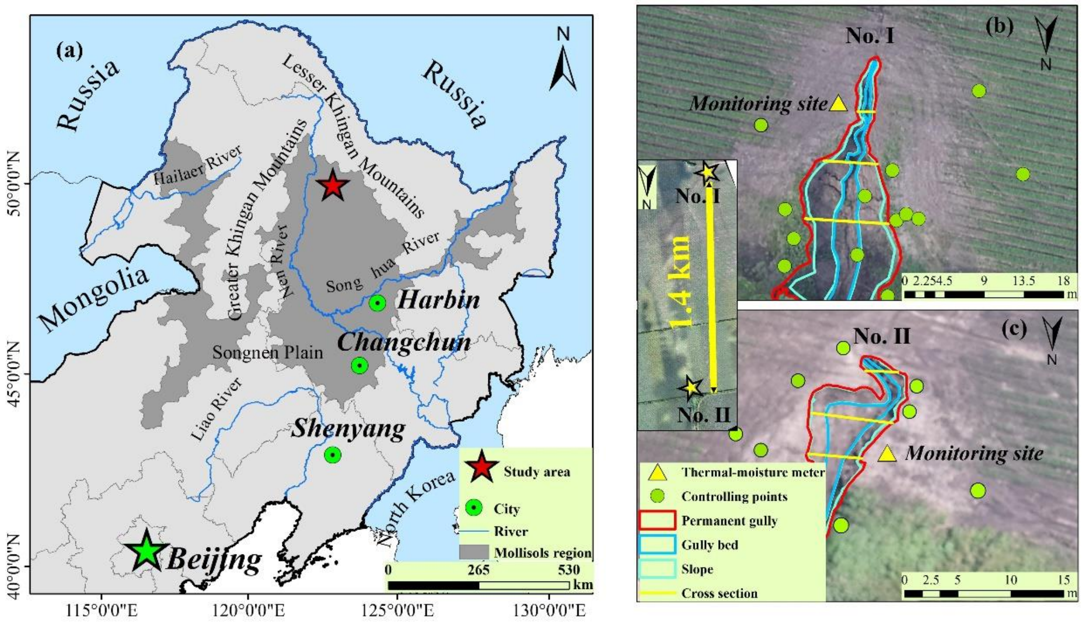
Step 2. Following manual screening to ensure the removal of any residual vegetation layer point clouds, the elevation data was regenerated, yielding a processed Digital Elevation Model (DEM) for the watershed.

Step 3. The erosion mainly occurs in the slope area and the gully bed area. For sites beyond the gully area, the topography change does not consider in our works as these sites are flatten and not in the gully area. Therefore, gully edges were delineated through visual interpretation of RGB optical images, with efforts made to exclude vegetation on the banks to the greatest extent possible.

The DEM was resampled to 0.10 m using ArcGIS 10.8 software. Ground control points were employed to perform local precise registration of the drone aerial imagery within ArcGIS 10.8, thereby minimizing errors in gully delineation. These ground control points were also utilized to enhance the accuracy of three DEMs.

Comment: Fig 2 need a figure to show the locations of the two gullies in the catchment.
Replies: Done.

The gully head of the two gullies are merely 1.4 km. In the revised process, we updated the location of the two gullies, and texted them in figure 1.



Comment: Fig 4. "Areal erosion intensity" is very confusion, I guess your means the volumetric changes divided by the area of the locations. If so, just "Erosion per unit area" is better. Also in the text.
Replies: Done.

We adopt your good suggestion here.

We modified the areal erosion intensity to erosion per unit area in figure 4 and figure 11. Also, all of the “areal erosion intensity” in the text (including the figure caption) were modified to “erosion per unit area”.

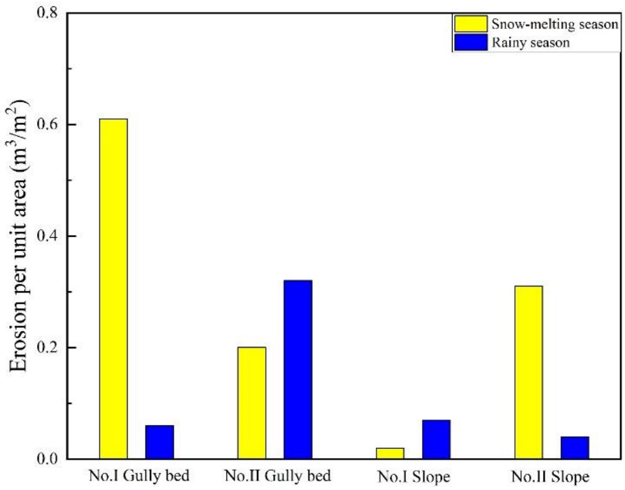


Fig. 4. Differences in the erosion per unit area for gully bed and over-steepen slope

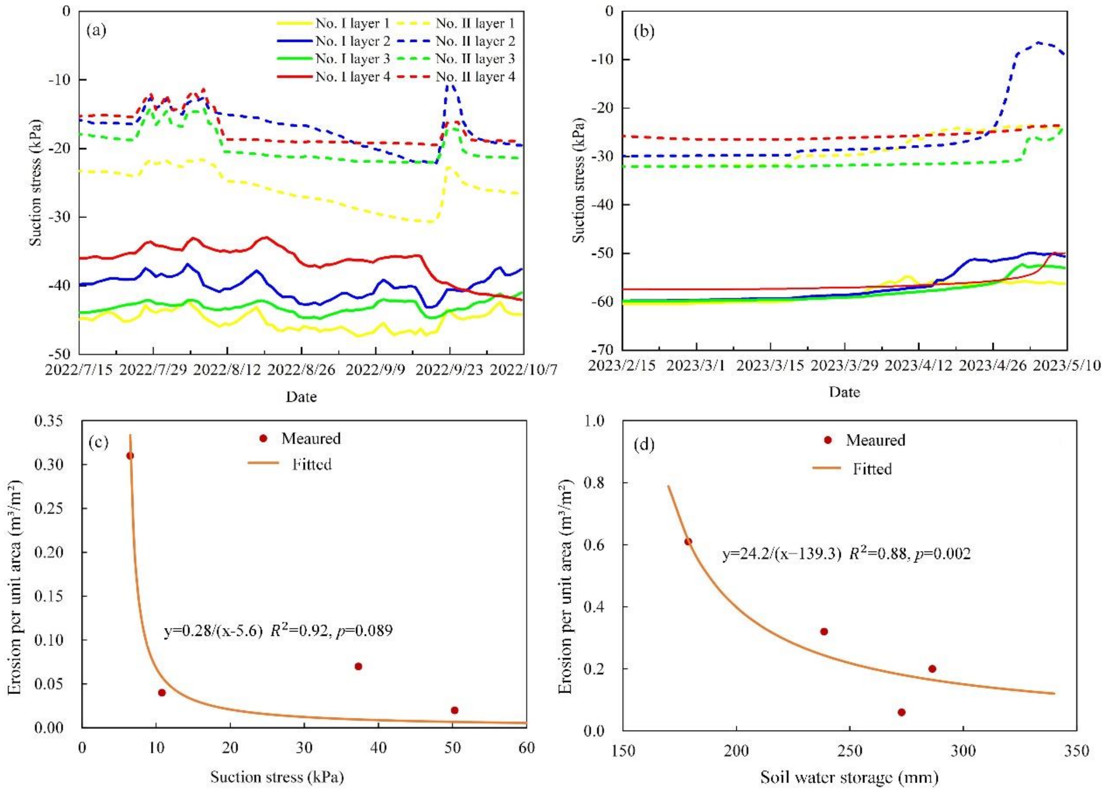


Fig. 11. Relationship between hydrology and the hydro-mechanical state with the erosion intensity. **(a)** Suction stress during the rainy season. **(b)** Suction stress during the snow-melting season. **(c)** erosion per unit area on over-steepen slope decreases with suction stress. **(d)** erosion per unit area on channel bed decreases with water storage amount.