Responses to Referee Comments

Manuscript ID: egusphere-2025-6098
Title: [Elucidating loessal landslide initiation in wood- and shrub-land by hydro-mechanical heterogeneity]

Dear Reviewers,

We thank you for your constructive comments on our manuscript. Your feedback has greatly improved the clarity and rigor of the paper. We have carefully revised the manuscript accordingly and have provided a consolidated, point-by-point response to all comments from Referee 1 and Referee 2. All revisions are reflected in the tracked-changes version of the manuscript.

Comment form RC1 and the replies

Comment 1: Line 158: What are the capital letters in the figure 4(b)?
Replies: Thank you for pointing this out.

We agree that the meaning of the capital letters was not clarified in the original caption. The capital letters in Figure 4 label corresponding points in the plot and serve as common reference markers across panels (a–d). We have added the following clarification to the figure caption: "Capital letters denote corresponding points shared across panels (a–d)."

Before revision:

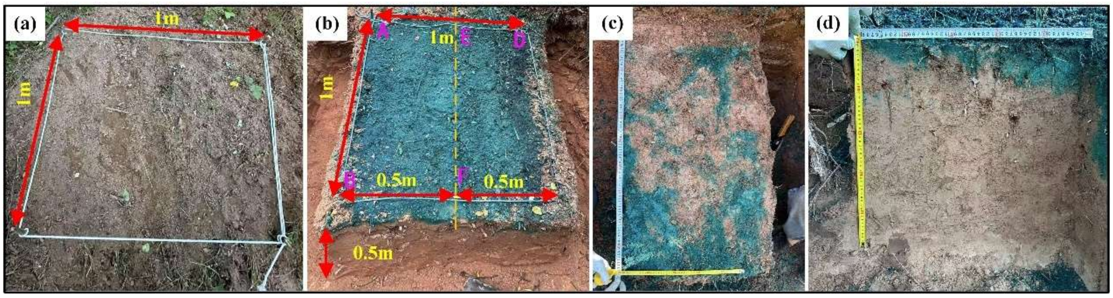

Figure 4. Dye tracer experiments and preferential flow pathways examination. (a) Experimental plot after vegetation removal. (b) Experimental plot after 24 h of brilliant blue solution spraying. (c) Horizontal dye-stained profile. (d) Transverse dye-stained profile.

After revision:

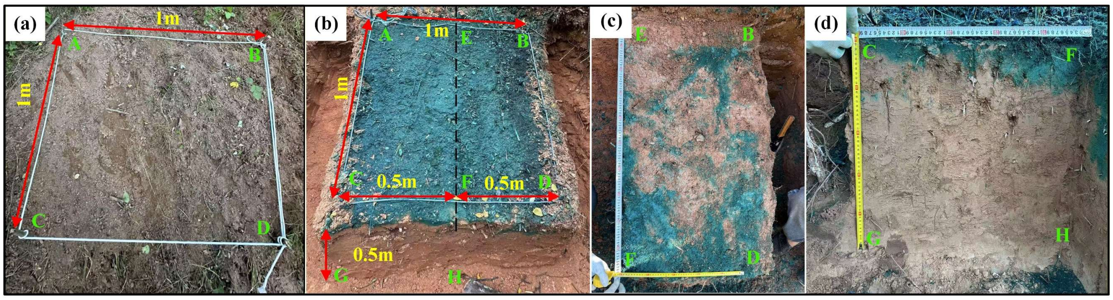

Figure 4. Dye tracer experiments and preferential flow pathways examination. (a) Experimental plot after vegetation removal. (b) Experimental plot after 24 h of brilliant blue solution spraying. (c) Dye-stained profile parallel to the slope surface. (d) Dye-stained profile along the gravity direction. Capital letters denote corresponding points shared across Fig. 4a–d.

Comment 2: Lines 135-136: Indicate the slope gradients for which dye tracer experiments were conducted for woodland and shrubland, respectively.

Replies: Done.

Revised as suggested. We have added the slope angles of the dye tracer experiment sites in Lines 135-136: 36° for the woodland site and 38° for the shrubland site.

Before revision:

Dye tracer experiments were conducted on vegetated slopes near the soil moisture monitoring sites to examine the preferential flow pathways (Fig. 1d). An electric sprayer was used to spray a 4 g·L^{-1} brilliant blue solution onto a 100 cm × 100 cm plot (Figs. 4a and 4b)

After revision:

Dye tracer experiments were conducted on vegetated slopes near the soil moisture monitoring sites to examine the preferential flow pathways (Fig. 1d). The slope angles were 35.8° at the woodland site and 38.2° at the shrubland site. An electric sprayer was used to spray a 4 g·L^{-1} brilliant blue solution onto a 100 cm × 100 cm plot (Figs. 4a and 4b).

Comment 3: Line 208: Provide evidence supporting the claim that the landslide point density in woodland is about 50% lower than in shrubland under similar conditions.

Replies: Done.

This statement was intended to be supported by the statistical results presented in Fig. 5a. To avoid ambiguity, we have revised the text to explicitly cite the evidence and removed the “about 50%” wording.

Before revision:

The *A*–*S* relationship shows that, at similar slope gradients, landslides in woodland require larger upslope contributing areas than those in shrubland. This suggests that, compared with landslides in shrubland, those in woodland may require higher rainfall-intensity thresholds, steeper slopes, or both, for initiation. As a result, landslide point density in woodland is about 50% lower than in shrubland under similar conditions.

After revision:

The *A–S* relationship shows that, at similar slope gradients, landslides in woodland require larger upslope contributing areas than those in shrubland. This suggests that, compared with landslides in shrubland, those in woodland may require higher rainfall-intensity thresholds, steeper slopes, or both, for initiation. Consistent with this, shrubland shows a higher landslide point density than woodland (1.56 times; Fig. 5a).

Comment 4: Line 283: Replace S-50 with S-85 in Figure 9(b).

Replies: Done.

In Fig. 9(b), the label has been corrected from “S-50” to “S-85”.

Before revision:

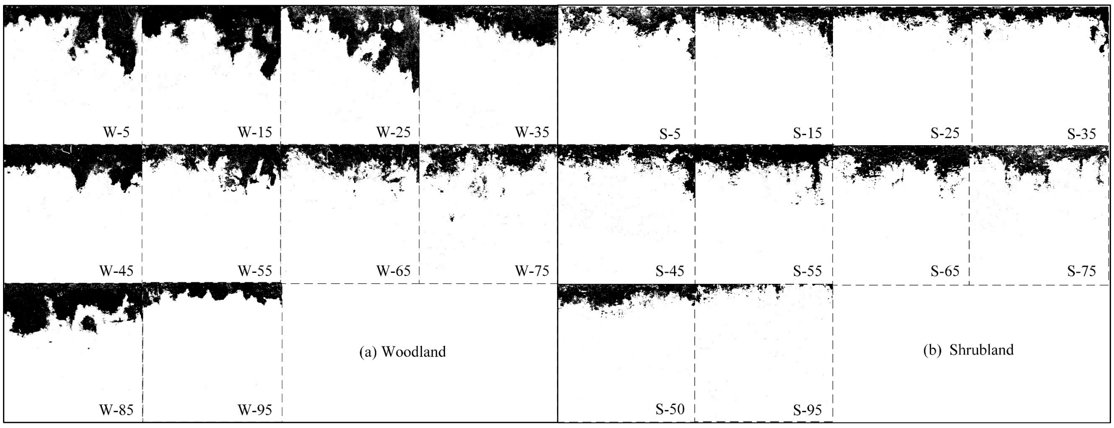

Figure 9. Schematic dye-stained vertical soil profiles at different hillslope positions. (a) Woodland profile; (b) Shrubland profile. Numbers from 0 to 100 denote relative slope positions, with lower values indicating locations near the slope base.

After revision:

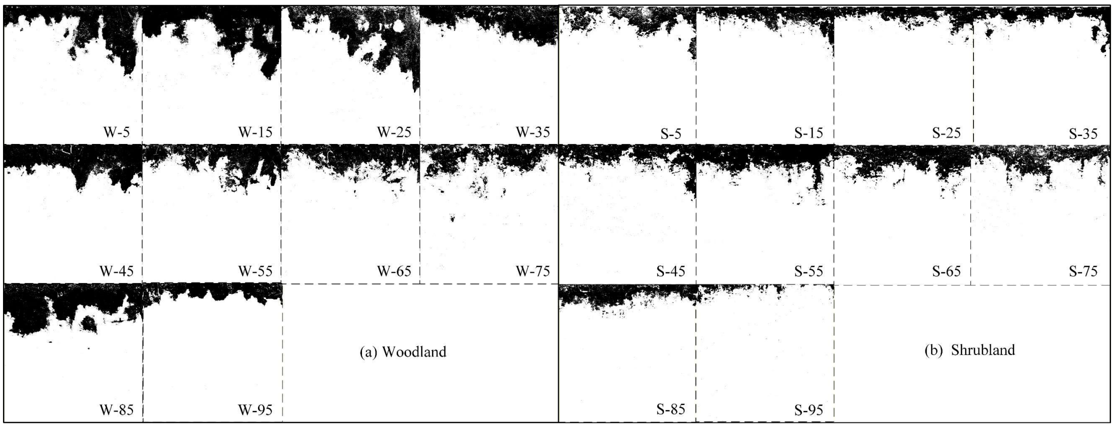

Figure 9. Schematic dye-stained vertical soil profiles at different hillslope positions. (a) Woodland profile; (b) Shrubland profile. Numbers from 0 to 100 denote relative slope positions, with lower values indicating locations near the slope base.

Comment 5: Lines 323-324: I suspect that the tensile strength varies significantly depending on tree species. Could it be due to differences in the tensile strength possessed by constituent species, rather than differences between woodland and shrubland?

Replies:

We acknowledge that tensile strength can vary among woody species. Accordingly, our interpretation is explicitly confined to the monospecific stands dominated by *Robinia pseudoacacia* (woodland) and *Rosa xanthina* (shrubland) investigated in this study, rather than being generalized to all woodland and shrubland types.

The woodland–shrubland comparison was conducted using pure stands dominated by a single species, rather than in mixed communities. The sampling plots were established within a pure *Robinia pseudoacacia* woodland and a pure *Rosa xanthina* shrubland, with no other woody species present, which reduced the potential for confounding effects from multi-species composition on strength-related parameters. In addition, the two sites were adjacent and located within the same catchment, with comparable background soil conditions, helping to minimize non-vegetation influences on root–soil composite properties.

To avoid ambiguity due to unclear phrasing, we have added site information to the Methods, Results, and Conclusions sections. These additions clarify that each study site is dominated by a single woody species (woodland: *Robinia pseudoacacia*; shrubland: *Rosa xanthina*).

Before revision:

In the study area, the woodland has an open structure due to sparse to moderate tree density and high canopy height (Fig. 3a), whereas the shrubland has a closed structure because of high density and low canopy height (Fig. 3b). Both land types have a well-developed herbaceous layer.

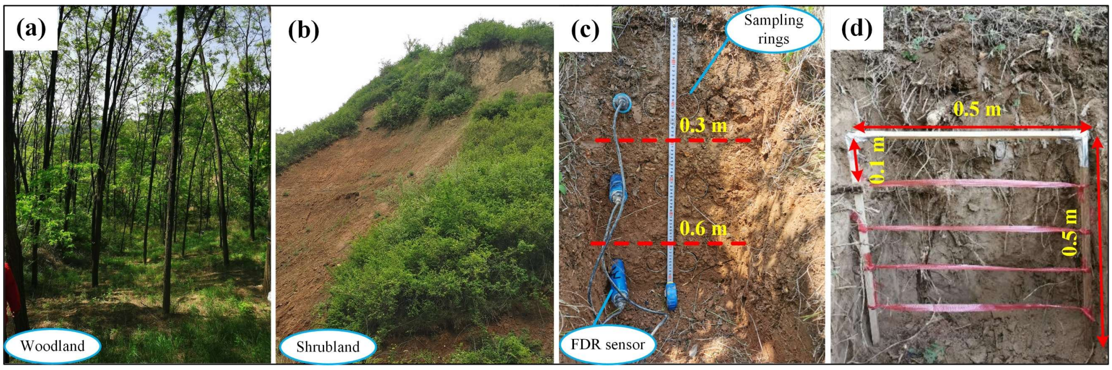

Figure 3. Soil moisture monitoring and soil and root sampling. (a) Open woodland dominated by *Robinia pseudoacacia*. (b) Close-structure shrubland dominated by *Rosa xanthina*. (c) Trench wall showing soil sampling and FDR sensor installation. (d) In situ root counting and sampling at 0.1 m depth intervals.

After revision:

In the study area, the woodland has an open structure due to sparse to moderate tree density and high canopy height (Fig. 3a), whereas the shrubland has a closed structure because of high density and low canopy height (Fig. 3b). Each study site is dominated by single woody species, with Robinia pseudoacacia in the woodland and Rosa xanthina in the shrubland. Both land types have a well-developed herbaceous layer.

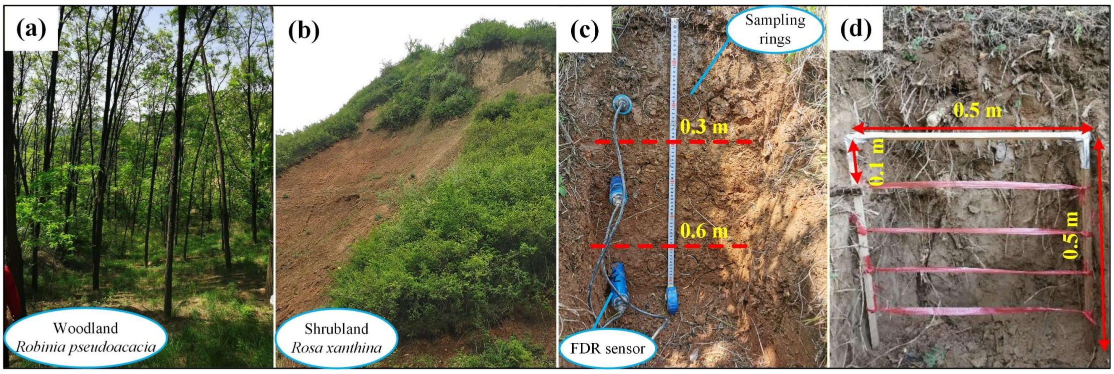

Figure 3. Soil moisture monitoring and soil and root sampling. (a) Open woodland dominated by *Robinia pseudoacacia*. (b) Close-structure shrubland dominated by *Rosa xanthina.* (c) Trench wall showing soil sampling and FDR sensor installation. (d) In situ root counting and sampling at 0.1 m depth intervals.

Before revision:

Root spatial distribution and mechanical properties differ markedly between woodland and shrubland soils (Figs. 11a, 11b, and 11c). Field measurements indicate that maximum rooting depths in woodland and shrubland are close to their respective mean landslide depths, at 0.84 m in woodland and 0.54 m in shrubland. This consistency indicates a close relationship between root distribution and landslide depth. Compared with shrubland, roots in woodland mobilize greater root cohesion at a given root diameter and exhibit a larger specific root area. These roots therefore create a more extensive root-soil contact interface and form a mechanically stronger root-soil composite.

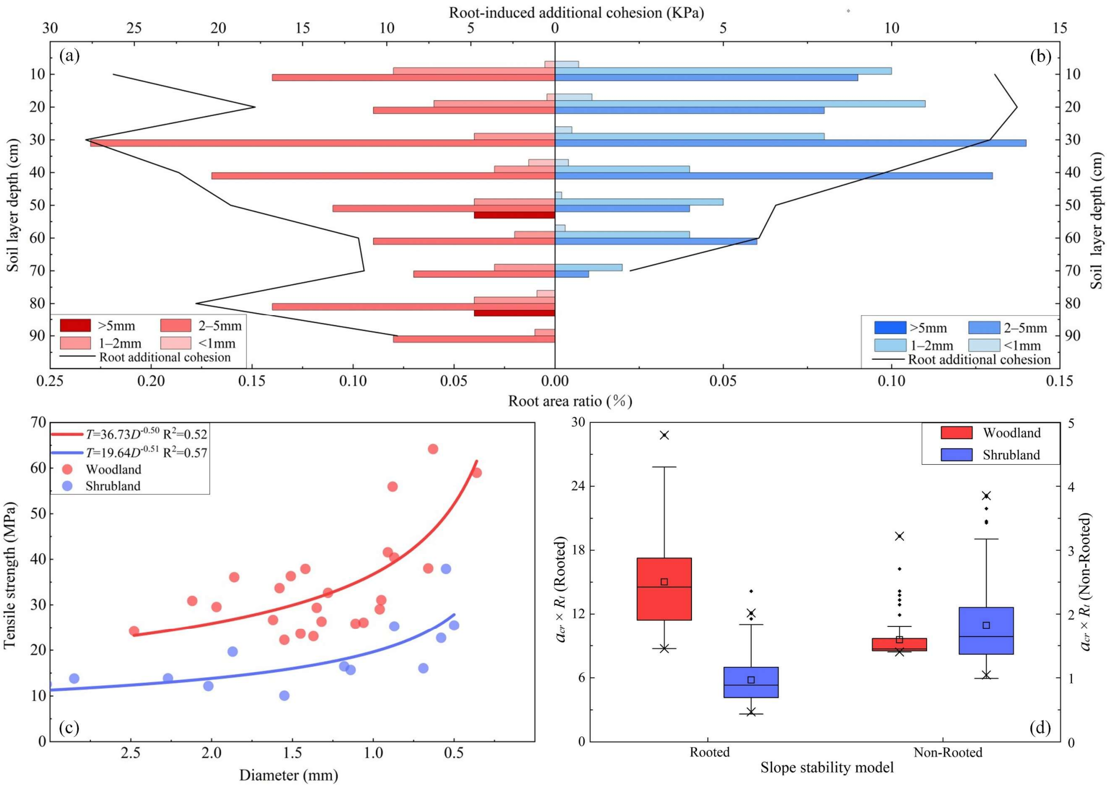

Figure 11. Mechanical indices of slope stability in woodland and shrubland. **(a)** Root area ratio and root-induced cohesion in woodland; **(b)** Root area ratio and root-induced cohesion in shrubland; **(c)** Relationship between root tensile strength and diameter; **(d)** Slope-stability models for woodland and shrubland. The definitions of the whiskers are given in the caption of Fig. 5.

After revision:

Root spatial distribution and mechanical properties differ markedly between woodland and shrubland soils (Figs. 11a, 11b, and 11c). Field measurements indicate that maximum rooting depths in *Robinia pseudoacacia* and *Rosa xanthina* are close to their respective mean landslide depths, at 0.84 m in *Robinia pseudoacacia* and 0.54 m in *Rosa xanthina*. This consistency indicates a close relationship between root distribution and landslide depth. Compared with *Rosa xanthina*, roots in *Robinia pseudoacacia* mobilize greater root additional cohesion at a given root diameter and exhibit a larger specific root area ratio (*RAR*). These roots therefore create a more extensive root-soil contact interface and form a mechanically stronger root-soil composite.

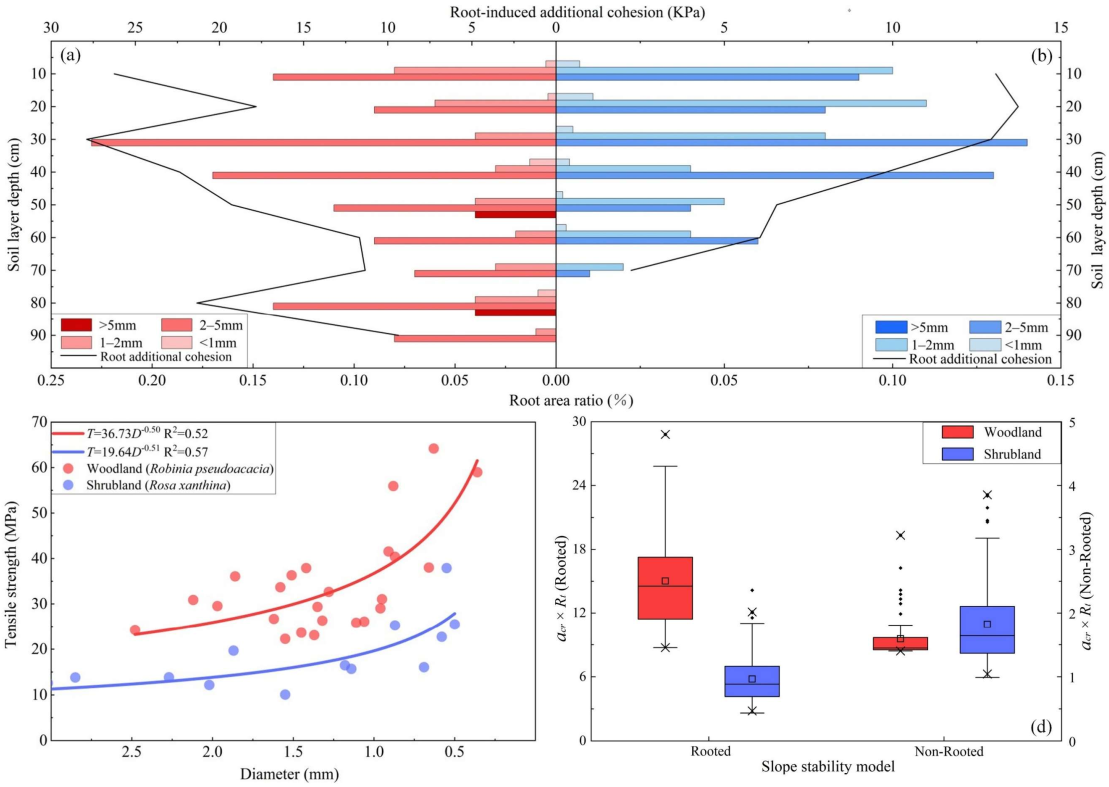

Figure 11. Mechanical indices of slope stability in woodland and shrubland. (a) Root area ratio and root-induced cohesion in woodland (*Robinia pseudoacacia*); (b) Root area ratio and root-induced cohesion in shrubland (*Rosa xanthina*); (c) Relationship between root tensile strength and diameter; (d) Slope-stability models for woodland and shrubland. The definitions of the boxplots is given in the caption of Fig. 5.

Before revision:

In this work, we addressed the landslide initiation in woodland and shrublandby landslide spatial patterns, hydrological response, and slope failure resistance.

After revision:

In this study, we systematically examined landslide initiation processes in two contrasting vegetated landscapes: Robinia pseudoacacia–dominated woodlands and Rosa xanthina–dominated shrublands, focusing on hydro-mechanical heterogeneity.

Comment 6: Lines 387-388: These descriptions appear to differ from the results in Figure 11(a) and Figure11(b).

Replies: Thank you for pointing this out.

Upon checking, we found that the statement in Lines 387–388 (Conclusion 3) did not fully align with the results shown in Figs. 11a and 11b. We have revised Conclusion 3 accordingly based on the results in Figs. 11a and 11b.

Before revision:

Woodland roots concentrated at 10–25 cm provides greater root cohesion, greater slope failure resistance, and higher slope stability than shrubland roots confined to 0–10 cm depth. Therefore, the sediment production from landslide erosion in Chinese Loess Plateau may differ in various forest types, which deserves further study in future.

After revision:

Woodland roots extend deeper and span a wider depth range than shrubland roots. Within the same depth interval, root additional cohesion and RAR are also higher than those in shrubland. These patterns indicate stronger root-network reinforcement in woodland soils and lower susceptibility to shallow landslides than in shrubland. Therefore, the sediment production from landslide erosion may differ in various forest types, which has been rarely addressed and deserves further study in future.

Comment form RC2 and the replies

Comment 1: Check this sentence: it looks like there is too many "consistent".

Replies: Done.

Before revision:

The landscape dissection-rainfall index indicates that steep woodland slopes have lower landslide susceptibility than steep slopes in shrubland, consistent with the lower susceptibility is consistent with the lower landslide density in woodland than in shrubland.

After revision:

The landscape dissection-rainfall index indicates lower landslide susceptibility on steep woodland slopes than on steep shrubland slopes, consistent with the lower landslide density in woodland relative to shrubland.

Comment 2: For comparison, it would be nice to use international climatic standards, e.g. the Koeppen-Geiger classification.

Replies: Done.

Before revision:

The study area lies in the transition zone between semi-humid and semi-arid climates, with a mean annual temperature of 9.9°C and a mean annual precipitation of 579.1 mm.

After revision:

The area has four distinctive seasons and a cold semi-arid climate . The annual precipitation is approximately 579.1 mm, and the mean annual temperature is 9.9°C.

Comment 3: Add the specific versions of Pix4D, Photoshop CS, and Image-Pro Plus used in the study.

Replies: Done.

Before revision:

(1) Pix4D software was used to generate ortho-mosaics and DEMs.

(2) Profile images were captured with a digital camera at a fixed distance and with a parallel orientation, and subsequently processed using Photoshop CS and Image-Pro Plus.

After revision:

(1) Pix4Dmapper (version 4.6, Pix4D SA, Switzerland) was used to generate ortho-mosaics and DEMs.

(2) Profile images were captured with a digital camera at a fixed distance and in a parallel orientation, and subsequently processed using Adobe Photoshop (version 2021; Adobe Inc., USA) and Image-Pro Plus (version 6.0; Media Cybernetics, USA).

Comment 4: Add the specific directional information for the meteorological station located at the Caijiachuan Forest Station.

Replies: Done.

Before revision:

A meteorological station at Caijiachuan Forest Station is located about 2 km from the study area.

After revision:

A meteorological station at Caijiachuan Forest Station is approximately 2 kilometers to the northwest of the study area.

Comment 5: Replace "indicates" with "indicate".

Replies: Done.

Before revision:

Positive or negative values of R_C indicates whether the increase in soil-water storage exceeds or falls below the rainfall input.

After revision:

Positive or negative values of R_C indicate whether the increase in soil-water storage exceeds or falls below the rainfall input.

Comment 6: Replace "Moving to the R…" with "Moving R to the…".

Replies: Done.

Before revision: Moving to the R left-hand side yields the right-hand side of Eq. (4) in an integrated form involving only soil mass parameters:

After revision:

Moving R to the left-hand side yields the right-hand side of Eq. (4) in an integrated form involving only soil mass parameters:

Comment 7: Replace "whiskers" with "boxplots".
Replies: Done.
Before revision:

(1) Figure 6. Upslope contributing area and slope gradient condition. **(a)** upslope contributing area and mean slope as a function of slope aspect; **(b)** upslope-contributing area vs. mean slope gradient above the landslide area. The definition of the boxplots is given in the caption of Fig. 5. Circles indicate mean slopes, with radius proportional to the number of landslides. A power-law regression is fitted to the bin-averaged data.

(2) Figure 11. Mechanical indices of slope stability in woodland and shrubland. **(a)** Root area ratio and root-induced cohesion in woodland (*Robinia pseudoacacia*); **(b)** Root area ratio and root-induced cohesion in shrubland (*Rosa xanthina*); **(c)** Relationship between root tensile strength and diameter; **(d)** Slope-stability models for woodland and shrubland. The definitions of the whiskers are given in the caption of Fig. 5.

After revision:

(1) Figure 6. Upslope contributing area and slope gradient condition. **(a)** upslope contributing area and mean slope as a function of slope aspect; **(b)** upslope-contributing area vs. mean slope gradient above the landslide area. The definition of the boxplots is given in the caption of Fig. 5. Circles indicate mean slopes, with radius proportional to the number of landslides. A power-law regression is fitted to the bin-averaged data.

(2) Figure 11. Mechanical indices of slope stability in woodland and shrubland. **(a)** Root area ratio and apparent cohesion in woodland (*Robinia pseudoacacia*); **(b)** Root area ratio and apparent cohesion in shrubland (*Rosa xanthina*); **(c)** Relationship between root tensile strength and diameter; **(d)** Slope-stability models for woodland and shrubland. The definition of the boxplots is given in the caption of Fig. 5.

Comment 8: For Fig. 5(a) and (b), the label "slope-gradient class" is missing from the plots, and the caption for Fig. 5 does not explain what the X symbols represent.
Replies: Done.
Before revision:

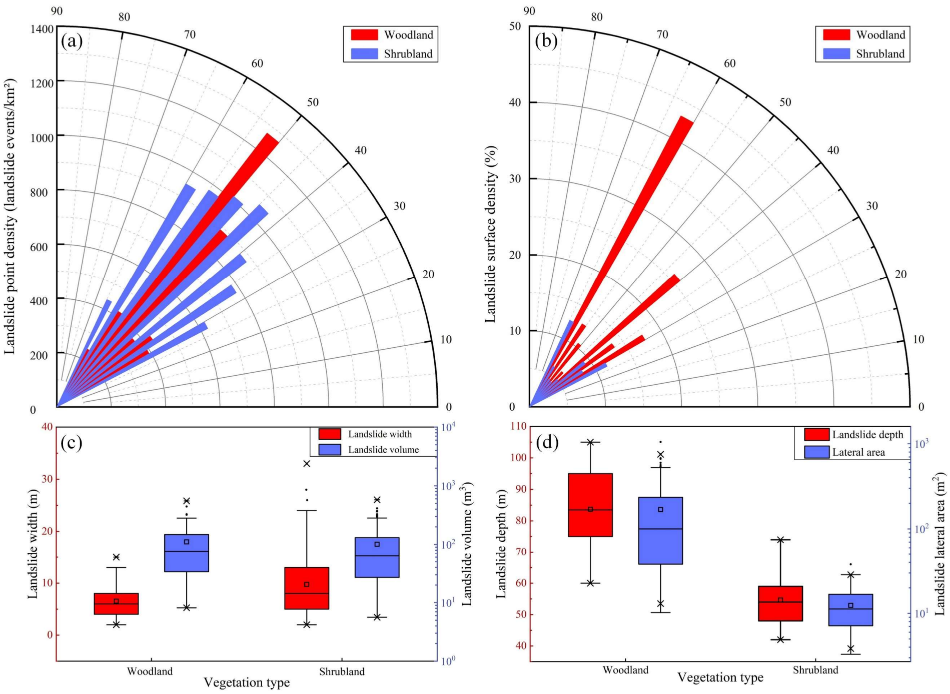

Figure 5. Landslide characteristics in woodland and shrubland. **(a)** point density by slope-gradient class; **(b)** areal density by slope-gradient class; **(c)** landslide depth and lateral area; and **(d)** landslide width and volume. The three crossing lines of box show decreasing order of 75th quantile (Q_3), median (Q_2), and 25th quantile (Q_1). The box length is the interquartile range (IQR=Q_3-Q_1). The small square is the average value. The upper and lower limit of whiskers are Q_3+1.5IQR andQ_1-1.5IQR, respectively. The whiskers extend to the minimum and maximum values, except for mild outliers, which are shown as black dots.

After revision:

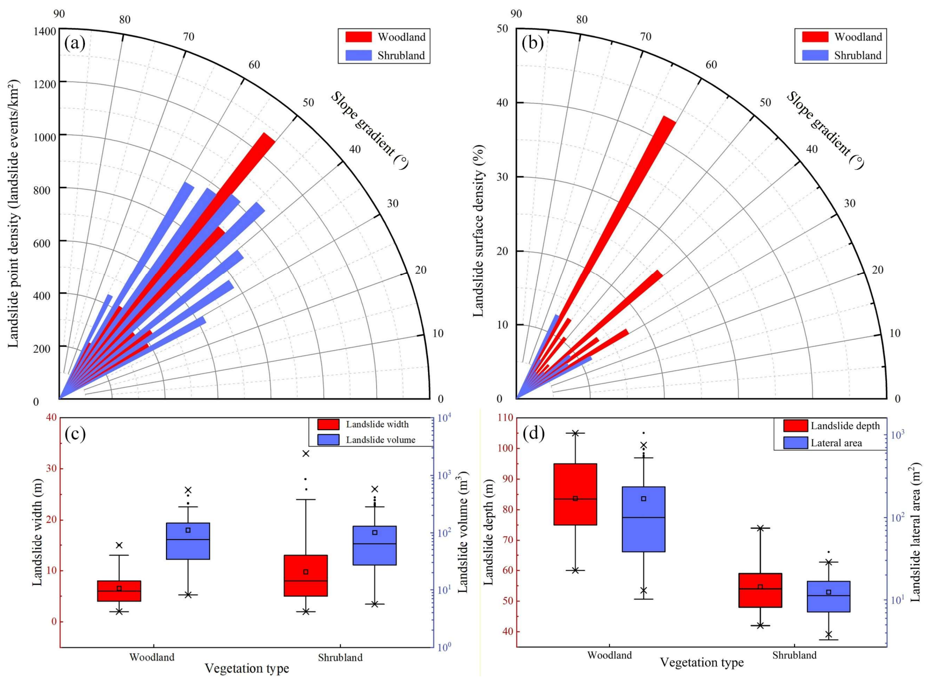

Figure 5. Landslide characteristics in woodland and shrubland. **(a)** point density by slope-gradient class; **(b)** areal density by slope-gradient class; **(c)** landslide depth and lateral area; and **(d)** landslide width and volume. The three horizontal-lines of box show decreasing order of 75th quantile (Q_3), median (Q_2), and 25th quantile (Q_1). The box length is the interquartile range (IQR=Q_3-Q_1). The small square is the average value. The cross symbols denote the 1st and 99th percentiles. The upper and lower limit of whiskers are Q_3+1.5I QR and Q_1-1.5 IQR, respectively. The whiskers extend to the most extreme values within these limits; mild outliers are shown as black dots.

Comment 9: In Table 1, please define what the superscripts "d" and "w" represent, and replace "moisture" with "water content".

Replies: Done.

Before revision:

Table 1. Parameters describing the soil and water characteristic curve (SWCC) and the hydraulic conductivity function (HCF) from Hydrus 1D

Parameters	Definition	Woodland	Shrubland
θ_s^d	Saturated moisture	0.500	0.480
θ_s^w		0.493	0.379
θ_r	Residual moisture	0.055	0.086
n^d	The pore size distribution	1.58	2.19
n^w	parameter	1.69	1.88
a^d (KPa^{-1})	The inverse of the air entry	5.461×10^{-3}	6.294×10^{-3}
a^w (KPa^{-1})	pressure head	0.646	0.596
K_s^d (cm·s^{-1})	Saturated hydraulic	2.3×10^{-5}	5.4×10^{-6}
K_s^w (cm·s^{-1})	conductivity	7.1×10^{-2}	5.0×10^{-3}

After revision:

Table 1. Parameters describing the soil and water characteristic curve (SWCC) and the hydraulic conductivity function (HCF) from Hydrus 1D

Parameters	Definition	Woodland	Shrubland
θ_s^d	Saturated water content	0.500	0.480
θ_s^w		0.493	0.379
θ_r	Residual water content	0.055	0.086
n^d	The pore size distribution	1.58	2.19
n^w	paramenter	1.69	1.88
a^d (KPa^{-1})	The inverse of the air entry	5.461×10^{-3}	6.294×10^{-3}
a^w (KPa^{-1})	pressure head	0.646	0.596
K_s^d (cm·s^{-1})	Saturated hydraulic	2.3×10^{-5}	5.4×10^{-6}
K_s^w (cm·s^{-1})	conductivity	7.1×10^{-2}	5.0×10^{-3}

Notes: Superscripts "d" and "w" denote the drying and wetting processes, respectively.

Comment 10: "This flow pattern is consistent with differences soil-matrix hydraulic behavior differences inferred from SWCC and HCF… ", not clear, rewrite it.

Replies: Done.

This paragraph seems to be mysterious and don't clear. We rewrite it from the macropore domain matrix pore domain. Such revision shows more clear than previous paragraph.

Before revision:

Overall, woodland soils more readily develop a stable, efficient vertical percolation system with greater infiltration depth and stronger connectivity. This promotes deep water storage and redistribution. In contrast, insufficient pore connectivity in shrubland soils causes water to remain in shallow layers, prolonging surface wetness and slowing pore-water pressure recovery. Under intense rainfall, this condition favors saturation buildup and thus increases the likelihood of landslide initiation. This flow pattern is consistent with differences soil-matrix hydraulic behavior differences inferred from SWCC and HCF and provides a path-based complement to traditional hydraulic parameters.

After revision:

Overall, woodland soils more readily develop a stable, efficient vertical percolation system with greater infiltration depth and stronger connectivity. This promotes deep water storage and redistribution. In contrast, insufficient pore connectivity in shrubland soils causes water to remain in shallow layers, prolonging surface wetness and slowing pore-water pressure recovery. Under intense rainfall, this condition favors saturation buildup and thus increases the likelihood of landslide initiation. This flow pattern is consistent with the SWCC- and HCF-inferred differences in soil hydraulic behavior and provides direct, pathway-scale evidence of flow pathways, which cannot be resolved from the curve-derived hydraulic parameters alone.

Comment 11: "Quantifying how rainfall translates into changes in soil-water content is critical for analyzing rainfall-induced landslides in this region.", the sentence is true in any region.

Replies: Done.

We already therefore removed it, as the subsequent text already presents the region-specific hydrological context.

Before revision:

Quantifying how rainfall translates into changes in soil-water content is critical for analyzing rainfall-induced landslides in this region. To characterize how woodland and shrubland soils respond to rainfall, we group rainfall events into distinct episodes based on soil depth and in situ saturated hydraulic conductivity (Fig. 10a).

After revision:

To characterize how woodland and shrubland soils respond to rainfall, we group rainfall events into rain episodes based on soil depth and in situ saturated hydraulic conductivity (Fig. 10a).

Comment 12: Fig. 10c represents Rc vs Soil water storage, not Rc vs Rainfall.

Replies: Thank you for pointing this out.

Before revision:

A steeper R_C–rainfall regression slope indicates a more pronounced soil moisture response to rainfall.

After revision:

A steeper slope in the regression of R_C versus soil water storage indicates a stronger soil moisture response to rainfall.

Comment 13: Table 2, specify the difference between C' and Cr.

Replies: Done.

Before revision:

Table 2 Parameters describing the slope stability model

Parameters	Definition	Woodland	Shrubland
ρ_s (kg·m^{-3})	Dry soil density	1.37	1.41
θ (°)	Slope gradient	31.71–65.27	22.78–67.96
C' (kPa)	Effective cohesion	5.97	7.35
C_r (kPa)		18.59	10.36
φ (°)	Effective friction angle	18.67	14.50
z (m)	Landslide depth	0.84	0.54
K (mm·h^{-1})	Hydraulic conductivity	2.10	0.94

After revision:

Table 2 Parameters describing the slope stability model

Parameters	Definition	Woodland	Shrubland
ρ_s (kg·m^{-3})	Dry soil density	1.37	1.41
θ (°)	Slope gradient	31.71–65.27	22.78–67.96
C' (kPa)	Effective soil cohesion	5.97	7.35
C_r (kPa)	Root-induced cohesion	18.59	10.36
φ (°)	Effective friction angle	18.67	14.50
z (m)	Landslide depth	0.84	0.54
K (mm·h^{-1})	Hydraulic conductivity	2.10	0.94

Comment 14: Replace "acting as" with "playing"; "In this context, we focused the landslide initiation difference in two representative restoration forests from the hillslope hydrology and failure resistance heterogeneity.", not very clear.

Replies: Thank you for pointing this out.

Before revision:

Long-term vegetation restoration policies may result in the dominant soil erosion process shift from traditional wind and water erosion to landslides (Deng et al., 2022; Yang et al., 2024; Du et al., 2025; Liao et al., 2025). Ecological restoration forests not only increase surface cover, but extend their root systems into potential sliding layers, thereby substantially altering slope hydrological processes and mechanical properties, and acting as an important role in landslide initiation (Zhao et al., 2022; Cai et al., 2024; Chen et al., 2024; Lann et al., 2024). In this context, we focused the landslide initiation difference in two representative restoration forests from the hillslope hydrology and failure resistance heterogeneity.

After revision:

Long-term vegetation restoration policies may result in the dominant soil erosion process shift from traditional wind and water erosion to landslides (Deng et al., 2022;

Yang et al., 2024; Du et al., 2025; Liao et al., 2025). Ecological restoration not only increase surface cover, but the recovered vegetation extends their root systems into potential sliding layers, thereby substantially altering slope hydrological processes and mechanical properties, and playing an important role in landslide initiation (Zhao et al., 2022; Cai et al., 2024; Chen et al., 2024; Lann et al., 2024). In this context, our results highlight the hydro-mechanical heterogeneity across the *Robinia pseudoacacia*–dominated woodland and *Rosa xanthina*–dominated shrubland, and assessed its influence on landslide initiation.

Comment 15: The subject is "Woodland slopes" so the verb cannot be "enhance slope stability", rephrase the sentence**.**

Replies: Done.

Before revision:

Woodland slopes, with deep root systems and stable preferential flow channels, enhance slope stability, whereas shrubland slopes, limited by shallow root systems, are more prone to rapid surface failure.

After revision:

The deep root systems and stable preferential flow channels in woodland slopes may provide greater resilience against slope failure compared to shrubland slopes.

Comment 16: "while their role on landslide initiation hasn't been addressed," the pronoun "their" is ambiguous; "In this work, we addressed landslide initiation..., " the definite article "the" should be removed.

Replies: Done.

Before revision:

Vegetation recovery in Chinese Loess Plateau may cause the dominant soil erosion process shift from runoff drive to gravitational attraction, while their role on landslide initiation hasn't been addressed. In this work, we addressed the landslide initiation in woodland and shrubland by landslide spatial patterns, hydrological response, and slope failure resistance. Following results can be drawn:

After revision:

Vegetation recovery on the Chinese Loess Plateau has altered the dominant soil erosion process from runoff-driven erosion to gravity-driven mass movements. Though previous studies have extensively investigated vegetation effects on soil erosion, the specific role of vegetation in landslide initiation remains poorly understood. In this study, we systematically examined landslide initiation processes in two contrasting vegetated landscapes: Robinia pseudoacacia–dominated woodlands and Rosa xanthina–dominated shrublands, focusing on hydro-mechanical heterogeneity. Following results can be drawn: