Some revised manuscript has been listed below. The full revised manuscript is under preparation and will be uploaded soon.

1. In the Section 1, the review on the influential factors of landslide impact and erosion has been improved and more references have been added.

The initial paragraph:

"Such material interactions cannot be overlooked in the runout assessments of landslides in alluvial basins, especially for large-volume landslides. Experiments have been conducted and models have been proposed to quantify the erosion process and how it affects the landslide mobility. Crosta et al. (2015) pointed out the phenomenon of generation of impact waves and erosion in cases of collapse on alluvial deposits. Meanwhile, the research on the Oso landslide showed that a slightly lower porosity and water content in the erosive bed can lead to a far less mobile landslide (Iverson et al., 2015). Besides these factors, it has been found that the erosion efficiency and runout distance strongly depend on the inclination angle of the slope and the thickness of the erodible bed (Mangeney et al., 2010). These findings reveal important mechanisms of landslide erosion process. However, in alluvial basin settings, slope transitions between the basin margins and the basin floor are typically abrupt rather than gradual, which amplifies the effect of substantial impact forces from the landslide mass. Currently, the emphasis on landslide erosion neglects the impact interaction (Wang et al., 2014), simplifying the erosion mechanism, and underestimating the role it plays in controlling the landslide runout."

has been revised to:

"Such material interactions cannot be overlooked in the runout assessments of landslides in alluvial basins, especially for large-volume landslides. These interactions, from material impact to shear, involve complicated physical processes and are influenced by multiple factors. These factors include geomorphological parameters, such as landslide volume (Larsen et al., 2010), slope inclination angle, and the thickness of the erodible bed (Mangeney et al., 2010), as well as the internal geomechanical properties of the involved materials, such as water content or degree of saturation (Iverson et al., 2015; Liu et al., 2015), dilatancy that influences the pore pressure generation during landslide motion, and permeability, which determines how long the elevated pore pressure can be sustained (Vicari et al., 2025; Zhu et al., 2025). These

studies show that quantitatively modelling material interactions during landslide motion is highly challenging, both theoretically and numerically, and remains a very active research topic. Especially in alluvial basin settings, slope transitions between the basin margins and the basin floor are typically abrupt rather than gradual, which amplifies the impact effects exerted by the landslide mass. This highlights the importance of placing more emphasis on quantitively investigating impact interactions, which commonly occur together with erosion processes in such settings (Wang et al., 2015). Compared with the studies focusing solely on erosion effects, the combined impact-erosion interaction remains relatively unclear."

References:

Larsen, I. J., Montgomery, D. R., & Korup, O. (2010). Landslide erosion controlled by hillslope material. Nature Geoscience, 3(4), 247-251.

Mangeney, A., Roche, O., Hungr, O., Mangold, N., Faccanoni, G., & Lucas, A. (2010). Erosion and mobility in granular collapse over sloping beds. Journal of Geophysical Research: Earth Surface, 115(F3).

Liu, W., He, S., & Li, X. (2015). Numerical simulation of landslide over erodible surface. Geoenvironmental Disasters, 2(1), 19.

Iverson, R. M., George, D. L., Allstadt, K., Reid, M. E., Collins, B. D., Vallance, J. W., ... & Bower, J. B. (2015). Landslide mobility and hazards: implications of the 2014 Oso disaster. Earth and Planetary Science Letters, 412, 197-208.

Vicari, H., Tran, Q. A., Juel, M. M., & Gaume, J. (2025). The role of dilatancy and permeability of erodible wet bed sediments in affecting erosion and runout of a granular flow: Two-phase MPM–CFD simulations. Computers and Geotechnics, 185, 107307.

Zhu, L., Tang, X., He, S., Yang, Z., Liang, H., Lei, X., ... & Zhang, L. (2025). Geomorphology and sedimentology of the Nyixoi Chongco rock avalanche and implications for emplacement mechanisms. Journal of Geophysical Research: Earth Surface, 130(3), e2024JF007666.

Wang, F., Sun, P., Highland, L., & Cheng, Q. (2014). Key factors influencing the mechanism of rapid and long runout landslides triggered by the 2008 Wenchuan earthquake, China. Geoenvironmental Disasters, 1(1), 1.

2. More details about the MPM models we used in the study has been updated to the Method section. The new subsection on numerical model is listed below:

"Section 3.2 Impact-runout modelling by material point method

To further investigate how the duration of materials interaction, which is influenced by the material properties, controls both the impact and following runout processes, numerical simulations were conducted to quantitatively describe the entire runout process under different scenarios. Since Luanshibao landslide is an ancient case, it is difficult to precisely reconstruct the post-failure topography. Therefore, the model geometry (Fig. 3b) was established using the cross-sectional profile of an unfailed slope adjacent to the Luanshibao landslide (profile line is depicted in Fig. 2). The model has a total height of 850 m and includes a 50 m thick sediment layer. The slope of the sliding surface is 36°, consistent with the exposed surface of rupture.

Based on the observations that groundwater level was extremely shallow in the landslide area and to simplify the model, the materials used in the simulations except for the bedrock were all considered under saturated condition. For this case, a two-phase MPM for saturated soil framework was used. This framework follows the mixture theory that uses porosity to divide the contents of solid and liquid, and we did not vary the porosity through the simulations or spatially (Tang et al., 2025). This framework describes the coupling problem with four equations, in which the subscript s stands for the solid phase and l stands for the liquid phase. They are two conservation equations for the mixture (Eq. 1 and 2), one momentum equation for the liquid (Eq. 3), and one equation for the solid skeleton, depending on the choices of linear elastic model or Mohr-Coulomb model in this study.

$$\frac{d\overline{\varepsilon_L}}{dt} = \frac{1}{n}\left[(1-n)\nabla\cdot\boldsymbol{v}_S + n\nabla\cdot\boldsymbol{v}_S\right] \quad (1)$$

$$(1-n)\rho_S\frac{d\boldsymbol{v}_L}{dt} + n\rho_L\frac{d\boldsymbol{v}_L}{dt} = \nabla\cdot\boldsymbol{\sigma} + \rho_{sat}\boldsymbol{g} \quad (2)$$

$$n\rho_L\frac{d\boldsymbol{v}_L}{dt} - n\nabla p_L - n\rho_L\boldsymbol{g} + \frac{n^2\rho_L g}{k}(\boldsymbol{v}_L - \boldsymbol{v}_S) = 0 \quad (3)$$

In those equations, $\overline{\varepsilon_L}$ *is the effective volumetric strain, n is the porosity of the mixture,* $\boldsymbol{v}$ *is the velocity vector,* ρ *is the density,* $\boldsymbol{g}$ *is the gravitational acceleration, and k is the isotropic Darcy permeability which is controlled by intrinsic permeability and viscosity of the liquid in the simulations.*

In this study, the base of the slope described in Fig. 3b was considered to be consist of *granite bedrock, described by a linear elastic model. Both the sliding material and the erosive sediment layer are described using Mohr-Coulomb model, with effective friction angle determined from the prior monotonic ring-shear tests (see Appendix for details). The sliding material is considered as weathered granitic debris which should be relatively denser than the erosive layer that primarily composed of loose alluvial sediment. Based on the hydrogeological features from field observation (introduced in Section 3), both materials are modelled as in a saturated state. To comprehensively evaluate the influence of material properties on landslide impact and the following runout patterns, two parameters of both sliding material and erosive sediment, including Young's modulus E and Poisson ratio v, are varied and tested to see how the stiffness and compressibility of materials contribute to the impact depth, velocity, and final runout. The numerical simulation scenarios and the corresponding parameter values are list in the table below."*

	sliding mass	*erodible sediment*	*bedrock*
material type	*weathered granitic debris*	*alluvial sediment*	*granite*
constitutive model	*Mohr-Columb (undrained)*	*Mohr-Columb (fully coupled)*	*linear elastic*
initial porosity	*0.2*	*0.6*	*0.0*
solid density (kg/m^3)	*2699*	*2699*	-
liquid density (kg/m^3)	*1000*	*1000*	-
intrinsic permeability (m^2/s)	5×10^{-11}	5×10^{-11}	-
effective Poisson's ratio	*0.25~0.4*	*0.25~0.4*	*0.25*
effective Young's modulus (kPa)	1×10^{4}~1×10^{5}	1×10^{4}~1×10^{5}	4×10^{7}
effective friction angle (°)	*34*	*34*	-

'Tang, X., Liu, W., He, S., Zhu, L., Jaboyedoff, M., Zhang, H., ... & Huo, Z. (2025). Stabilized two-phase material point method for hydromechanical coupling problems in solid–fluid porous media. Geoscientific Model Development, 18(15), 4743-4758.

The model used is mainly referred to: Anura3D MPM Research Community (2022) Anura3D Scientific Manual version 2022'