Dear Editors and Reviewer:

Thank you for your letter and for the reviewers' comments concerning our manuscript entitled "A novel prediction method for shallow landslides in loess areas: A case study of the 2013 "7.25" Tianshui sliding-flow landslide in Gansu province, China" (ID: nhess-2022-135). Those comments are all valuable and very helpful for revising and improving our paper, as well as the important guiding significance to our researches. We have studied comments carefully and have made correction which we hope meet with approval. The authors upload the both file (one is revised with tracking word and the other is revised without tracking word). The main corrections in the paper and the responds to the reviewer's comments are as flowing:

Responds to the reviewer's comments:

Editor comments:
in view of the two reviewers' reports and after careful consideration of the manuscript and the issues raised by referee #3 after the major revision iteration, we still fall under the situation of the first review round, with one review which is good (minor revision) while the other recommends rejection. Due to this problem, I am forced to ask again for major revisions of the manuscript, as most of the flaws that were present in the original version seem to be still present.
My suggestion is to carefully read and try to address the comments of review #3, in particular:
Responds: Yes, we have read the comments of the both reviewers, and indeed their comments differ significantly. The main issue is the applicability of the Revised Infinite Slope Model (RISM). As we know, modifying or establishing a new model, or extending the application of a model to other areas, requires multiple revisions and improvements. The model we have established is no exception. The objective of the manuscript is proposing the Revised Infinite Slope Model (RISM) that corrects for any deficiencies associated with increased safety factors on slopes that are invariable and predicting regional shallow landslide. However, we cannot deny that there are shortcomings in this revised model, such as limited applicability to loose layer thickness and uneven rainfall infiltration. These situations are not adaptable and require further revision.

- please clarify the very important issue raised by the reviewer on the absence of soil on steep slopes of the study area, a thing which evidently would hinder the possibility of the development of shallow slides
Responds: It is very good suggestion, thanks very much. The aim of this manuscript is to study soil landslides. The infinite slope model is also suit for the soil landslide. This manuscript is based on the revised and improved form infinite slope model, so the Revised Infinite Slope Model (RISM) is only applicable to shallow soil landslides.

- also, if the slides are not shallow and affect the bedrock, the model you use (infinite slope) is probably not well suited to represent the geotechnics of the slope and therefore not apt at computing a reliable factor of safety
Responds: This issue is the same as the previous, because the infinite slope model has two hypotheses: one is that the length of the slope is much greater than the depth, and the second is the slope is mean soil slope. The manuscript is to study the loess (soil) shallow landslides and the

manuscript is based on the revised and improved form infinite slope model, so the Revised Infinite Slope Model (RISM) is only applicable to shallow soil landslides.

- please also explain and justify why those hypothetical shallow (or soil) slides would be triggered by long-duration rainfall, something that is contrary to prior knowledge

Responds: The manuscript is focused on the prediction of rainfall-induced loess shallow landslides. Additionally, the infinite slope model is specifically designed for forecasting rainfall-induced shallow landslides as well. Considering the research findings on the triggering factors of loess shallow landslides, it is evident that loess landslide occurrences are most sensitive to long-duration rainfall. Only prolonged rainfall can lead to soil saturation and the formation of sliding-flow characteristics. Therefore, the manuscript is the prediction of rainfall-induced loess shallow landslides.

- another important point: if the geotechnical properties of the affected materials are as stated (cohesion 5 kPa and friction 20°), how can you justify the stability of slopes with gradients overcoming 50°? This simple fact strongly compromises the basis of your work, according to reviewer #3 and according to the old report of reviewer #2, whose comments have not been answered properly. The response to this important point cannot be verbal but should include new data and maps demonstrating the validity of the basic hypotheses cited above as well as documenting the spatial distribution of slope angle and past landslide occurrences over the area, with some accompanying spatial statistics

Responds: It is very good suggestion, thanks very much. This is one of the contents to be studied in this manuscript. Due to the issue of the increase of safety factor in the infinite slope model with increasing slope (>45°) in calculating the stability of shallow landslides, this manuscript proposes the Revised Infinite Slope Model (RISM) using an equal differential unit method to correct for deficiencies when the safety factor remains unchanged or increases with increasing slope, greater than 40° as calculated using the Taylor slope infinite model. The slopes in the Loess Plateau region often have slopes above 45°, and even up to 80° (the slope is more than 40° account for 5.3%). At the same time, the slopes where shallow landslides occur in the Loess Plateau region often exceed 40° (the landslide is more than 50° account for 13.81%). Therefore, many slope stability calculation models and even soil erosion models are not applicable to the Loess Plateau region. The Revised Infinite Slope Model (RISM) proposed in this manuscript, in calculating slope stability, found that with increasing slope, the critical depth of the soil layer induced by rainfall-induced slope landslides decrease. So, at slopes greater than 50°, many shallow landslides often have a depth of only 10-20cm, which in the Loess Plateau region are often considered as soil erosion or surface soil movement. Therefore, while correcting the infinite slope model, this manuscript also provides the critical depth at different slopes and combines rainfall infiltration to calculate the critical rainfall forecast model for shallow landslides at different slopes in CLP. At the same time, this manuscript focuses only on rainfall-induced shallow landslides and restricts the application of the model to the Loess Plateau region. This model cannot be applied to landslides that are controlled by the strength of the soil structure or the structure and fissures of the rock-soil mass.

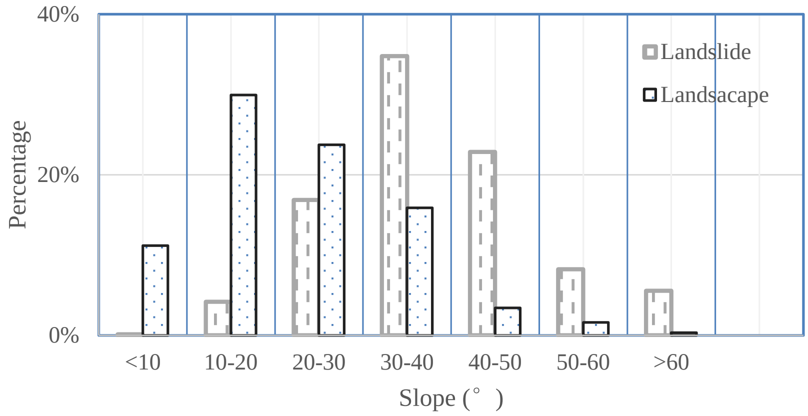

Figure 1 The slope distribution of the landslide and landscape

- finally, the infinite slope model makes the assumption that the sliding depth decreases with increasing slope gradient but the model doesn't take into account that also soil depth decreases as well with slope angle. According to reviewer #3, this seriously hampers the applicability of the method. This point as well needs an in-depth explanation and some counterproof to be considered valid.

Responds: It is very good suggestion, thanks very much. The study area in this manuscript is the Loess Plateau, and at the same time, this manuscript only focuses on shallow sliding-flow landslides induced by rainfall, and the application area of the model is limited to homogeneous soil cover areas. This model cannot be applied to landslides that are subject to the strength of the soil structure or the sliding controlled by the rock and soil structure or cracks.

In the Loess Plateau region, the thickness of loess often reaches more than 100m, and this thickness does not change with the change of slope, so this paper does not consider the issue that soil thickness decreases with the increase of slope.

Reviewing: 1

The authors mentioned that the main purpose of the manuscript is to improve the deficiency that the safety factor invariable or increases with the slope increasing when the slope is greater than 50° when Taylor infinite slope model is adopted. Then, to show that large amount of landslides was occurred in steep slopes (greater than 50°), the authors provide the Figure 1 in the "author response". But I could not understand how the shallow landslides has occurred in steep slope whose slope angle is greater than 50°. This is because shallow landslide could be occurred natural slope whose depth is less than 1-2m and steep natural slope (> 50°) does have this soil cover over bedrock.

Responds: Thank you very much. The main purpose of this manuscript is to revise the infinite slope model so that it can be applicable to steep slopes in the Loess Plateau region. The Loess Plateau region is widest distribution of soil slopes in China, where the thickness of loess often exceeds 100 meters. Loess exhibits typical water-sensitive characteristics and is prone to catastrophic failure and the formation of sliding-flow landslides. For example, the prolonged heavy rainfall in 2013, 2015, and 2021 resulted in thousands of sliding-flow landslide events in the Loess Plateau region.

Based on the distribution of these landslide events and field investigations, it is observed that many shallow landslides in the Loess Plateau region occur on slopes with gradients of over 40 degrees

(~10-15%, Zhuang et al., 2017; Shao et al., 2023). This is because the accumulation thickness of loess in the Loess Plateau region is large, and it has little relationship with the slope gradient. As a result, the risk and probability of sliding-flow landslides still exist on steep slopes (50°) in the Loess Plateau region.

At the same time, this manuscript focuses only on rainfall-induced shallow landslides and restricts the application of the model to the Loess Plateau region. This model cannot be applied to landslides that are controlled by the strength of the soil structure or the structure and fissures of the rock-soil mass.

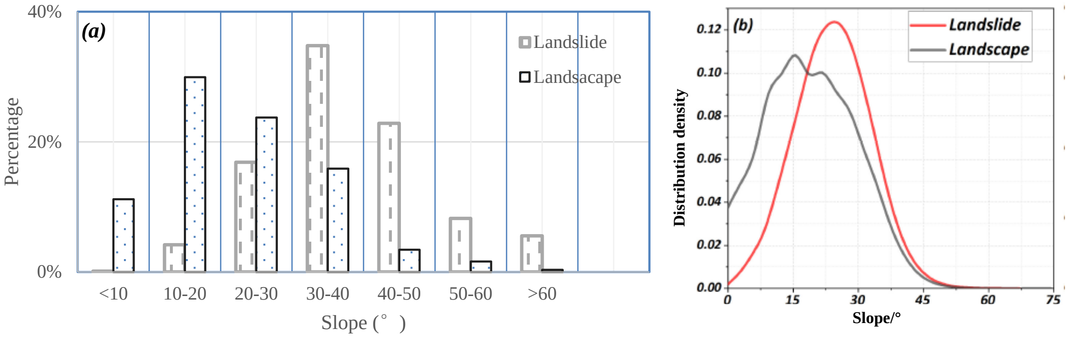

Figure 2 The slope distribution of the landslide and landscape (a, in this study; b, from Shao et al., 2023)

The authors considered that the shallow landslides were occurred in this study area due to prolong heavy rainfall and adopted infinite slope model in this analysis. The shallow landslide is typically occurred in natural slopes whose slope depth is less than 1 – 2 m. However, as shown figure 7(b), the steep slope (> 50°) will have very thin or almost 0 m soil depth. Therefore, the occurrence of shallow landslide is not practically possible. Or the landslide occurred in slopes with greater 50° may not be the shallow landslide, which means that infinite slope model cannot apply to those steep slope.

Responds: Thank you very much. As mentioned earlier, The Loess Plateau region is widest distribution of soil slopes in China, where the thickness of loess often exceeds 100 meters. Loess exhibits typical water-sensitive characteristics and is prone to catastrophic failure and the formation of sliding-flow landslides. For example, the prolonged heavy rainfall in 2013, 2015, and 2021 resulted in thousands of sliding-flow landslide events in the Loess Plateau region.

In this study, the revised infinite slope model was used to calculate slope stability. It was found that with increasing slope, the critical approximate liquid limit water content layer gradually decreases, but the rate of decrease slows, from 1.14 m at 20° to 0.47 m at 40°. This relationship can be expressed via the power-law. Therefore, when the slope is greater than 50 degrees, many shallow landslides have a sliding thickness of only 10-20cm, which is often attributed to soil erosion or surface soil movement in the Loess Plateau. Meanwhile, this study also provided the critical depth for different slopes and calculated the critical rainfall forecast model for shallow landslides under different slopes, considering rainfall infiltration. The steeper slopes have a higher probability of shallow landslides occurring, as rainfall infiltrates the soil and reduces its strength at a certain depth, triggering soil instability. It should be noted that this study focuses only on rainfall-induced shallow landslides and flow, and the application of the model is limited to the loess region. It cannot be applied to landslides controlled by soil structure strength, or rock-soil structures, and fractures.

In addition, cohesion and friction angle of slope materials in the study are 5 kPa and 20 °, respectively. Therefore, when we consider the cohesion and friction angle values (somewhat lower than typical values in other area), it is not easy to understand that this soil material can have steep slope over 50°.

Responds: Yes, it is certain that the loess will failure when the slope is greater than 50° with such low soil strength, However, the focus of this manuscript is to discuss the applicability of the infinite slope model under different slope, and to determine the relationship between the critical depth and slope required to trigger loess sliding-flow under rainfall. It has been found that with increasing slope, the critical approximate liquid limit water content layer gradually decreases, but the rate of decrease slows, from 1.14 m at 20° to 0.47 m at 40° according to field investigations and calculate. This relationship can be expressed via the power-law. This why we often observe shallow landslides occurring in steep areas with relatively low rainfall intensity. Therefore, when the slope is greater than 50 degrees, many shallow landslides have a sliding thickness of only 10-20cm, which is often attributed to soil erosion or surface soil movement in the Loess Plateau.

In order to persuade readers, the authors should provide the slope angle distribution map of the study area. In addition, the authors should provide the any pictures or proof that showing the shallow landslide occurred in high slope angle.

Responds: Thank you very much. The slopes in the Loess Plateau region often have slopes above 45°, and even up to 80° (the slope is more than 40° account for 5.3%). Based on the distribution of these landslide events and field investigations, it is observed that many shallow landslides in the Loess Plateau region occur on slopes with gradients of over 40 degrees (~10-15%, Zhuang et al., 2017; Shao et al., 2023). The maximum slope observed for shallow landslides is 69°, while the maximum slope of the study area's topography is 71° (Shao et al., 2023).

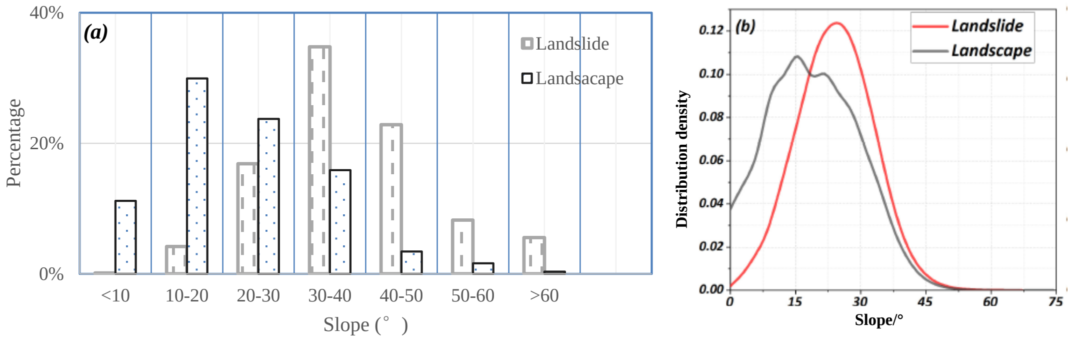

Figure 3 The slope distribution of the landslide and landscape (a, in this study; b, from Shao et al., 2023)

In addition, I should point out a serious problem in the authors' basic idea. As the authors showed in Fig. 7(b), the sliding depth decreases when slope angle increases. When slope is greater 50°, the we can imagine that the slope depth could be very shallow or almost close to 0 m. However, the authors did not consider that the slope depth could be decreased to very shallow or almost 0m when slope angle increases. As shown in Fig. 10, the authors considered fixed slope depth even if slope angle increases over 50° and I believe it causes miscalculation. Therefore, the revised infinite slope model could not be needed.

Responds: It is very good suggestion, thanks very much. Figure 7 presents the depth distribution of landslides induced by prolonged heavy rainfall based on field investigation. As mentioned in our manuscript, we surveyed approximately 83 landslide samples and obtained slope and sliding depth distribution maps. We found that the depth of the sliding-flow landslide had no correlation with the landslide area and had a negative correlation with the slope. With increasing slope, the depth of the landslide decreases, that is, the greater the slope, the shallower the sliding surface, and the smaller the slope, the greater the depth of the sliding surface. These findings align with the real observations we made in the field. However, as the slope continues to increase, the depth of the sliding surface decreases. Based on previous experience, sliding surfaces with depths within 10 cm are also common occurrences, especially in the Loess Plateau region. When rainfall infiltrates into the loess, the strength of the loess decreases. Shallow sliding-flow can be triggered in steep slope once the infiltration reduces the strength to a certain extent. This is why we often see bare areas in steeper slope regions of the Loess Plateau after rainfall because these steeper slope slopes are prone to shallow sliding-flow during prolonged rainfall. Through our statistics on existing landslides, we found that shallow sliding-flows with slopes greater than 50° accounted for 13.81% of the landslides induced by prolonged heavy rainfall in Tianshui in 2013. Furthermore, we compared the slope distribution of the landslides that occurred in this event with other interpreted distributions and found that landslides with slopes greater than 50° accounted for a certain proportion of the shallow sliding-flows induced by continuous heavy rainfall in Tianshui in 2013. The maximum slope observed for shallow landslides was 69°, while the maximum slope of the study area's topography was 71° (Shao et al., 2023).

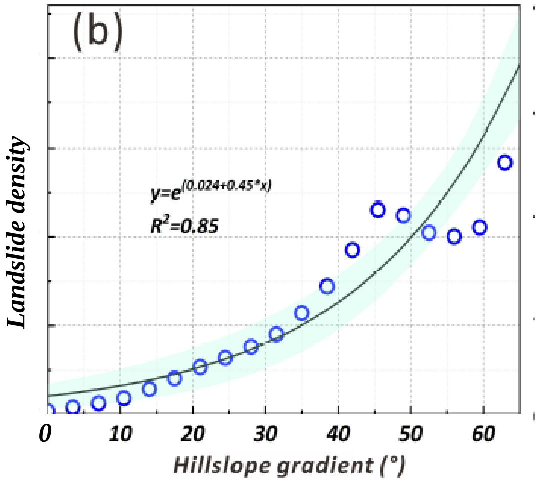

Figure 4 Map showing the relationship between the LAD and slope factors (from Shao et al., 2023)

Table 1 Statistical slope factor for the landslides and landscape area (from Shao et al., 2023)

Variable		Landslide	Landscape
Hillslope gradient [°]	Mean	25.5	20.5
	Max	69	71
	Min	0	0

Reviewing: 2

The manuscript was thoroughly revised according to the comments of reviewers. I suggest it should be accepted after a minor revision.

1.I suggest the title should be modified as “Shallow landslides stability evaluation in loess areas according to Revised Infinite Slope Model: A case study of the 2013 “7.25” Tianshui sliding-flow landslide in Gansu province, China”

Responds: It is very good suggestion, thanks very much. We have revised the manuscript title according to this suggestion.

2.The technical terms should be consistent through the whole manuscript, i.g. “liquid limit water content” should also be used in abstract instead of “ liquid limited water content”. Such mistakes should be avoided.

Responds: Thank you very much. The authors have revised the technical terms which not consistent in the text.

3.The English in this manuscript should be further revised.

Responds: Thank you very much. The manuscript has been polished by native English speaker.

Shao, X.; Ma, S.; Xu, C.; Xu, Y. Insight into the Characteristics and Triggers of Loess Landslides during the 2013 Heavy Rainfall Event in the Tianshui Area, China. Remote Sens. 2023, 15, 4304. https://doi.org/10.3390/rs15174304

Zhuang, J.Q., Peng, J.B., Wang, G.H., Javed, I., Wang, Y. and Li, W.: Prediction of rainfall-induced shallow landslides in the Loess Plateau, Yan’an, China, using the TRIGRS model, Earth Surface Processes and Landforms, 42(6), 915-927, doi:10.1002/esp.4050, 2017

Jiqnzi Zhuang, Jianbing Peng and Chenhui Du
jqzhuang@chd.edu.cn