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Elucidating the role of soil hydraulic properties on the aspect-dependent landslide initiation

Detailed Response to the Editor Jorge Isidoro

We sincerely thank your comments and reminding that there are some minor changes in the table 1 and the figures 4 and 6a, and the decision of moderate revision on our novelty work on the aspect-dependent landslide initiation.

We checked all the tables and figures, to ensure that the texts in tables and figures are correct. Well, we prepared the replies to answer all the comments from the reviewers. Importantly, we made an additional effort and taken some time for final revision of the manuscript, as some sentences could benefit from clarification to improve their readability. Also, we some help for improving the written English to meet the required high-standard of HESS, to present well-written papers.

Please see the point-to-point replies, the well-written and revised manuscript.

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Elucidating the role of soil hydraulic properties on the aspect-dependent landslide initiation

Detailed Response to the Reviewer1's Comments

We sincerely thank the Jorge Isidoro and reviewers for their constructive comments, helping to improve the quality of our manuscript. We are sorry for delaying answer the valuable comments because we are asked to stay at home for almost 2 months, due to the Coronavirus policy in Beijing and Beijing Forestry University. In such a condition, the team members read the comments and revised carefully after we are permitted to enter the office. With full consideration of the reviewers' suggestions, the manuscript has been carefully reshaped and we made point-by-point responses to address the comments of the reviewers.

Importantly, the editor Jorge Isidoro and reviewer 1 suggest the written English should be improved by a professional editing service. Meanwhile, an additional effort and final revision of the manuscript should be made to improve the readability. In the following, we answer all comments (set in black fonts) and give response (set in blue fonts). Quotes of the revision are set using a red font.

Reviewer #1:

1. The paper investigates the question whether land-sliding initiation at slopes is aspect-dependent. The obvious reason for potential differences - the radiation budget - is not discussed explicitly, but resulting processes - differences in plant root strength, the pore water pressure (or larger evapotranspiration at the south-exposed slope) are.

Response: Thanks for your suggestions.

The main reason for the difference of slope aspect in this article is the differential weathering of bedrock caused by solar radiation, which makes the rock and soil mass show differences in the hydrological properties of the slope. Because the vegetation on the sunny and shady slopes in this area is larch, which belongs to shallow root plants. The length of root system is about 0.4m, and it does not reach the sliding layer.

Therefore, the strength of root system is not a factor that causes the slope direction difference of landslide.

In the introduction part, we add a summary of the impact of solar radiation and vegetation roots on landslides to guide the main line of the article.

In some semi-arid environments of the Northern hemisphere, aspect-dependent landslide initiation during some extreme rainstorm events would provide valuable insight into the relative importance of different factors in developing accurate landslide susceptibility models (Ebel, 2015; Rengers et al., 2016; Li et al., 2021; Deng et al., 2022). These events provide thoughtful understanding about the amount of direct sunlight translate into differences in vegetation community, bedrock weathering, and soil development process (Fu, 1983; Wang, 2008; Bierman and Montgomery, 2014). These typical earth surface process indirectly affect hillslope hydrology and landscape dissection on hillslope scale. Importantly, rainfall-induced shallow landslides are one of the geomorphic agents on hillslope scale and governed by multiple factors, including hydrology, hillslope materials, bedrock underneath and the vegetation (Birkeland, 1999; Geroy et al., 2011; Lu and Godt, 2013). Currently, the observed aspect-dependent landslide initiation mainly attributes to the mechanical effect of plant roots, because the differences of vegetation on the south- and north-facing slope are easier to examine and more obvious than other factors (Li et al., 2021; Timilsina et al., 2021; Dai et al., 2022; Deng et al., 2022). However, it is no denying that vegetation succession is far slowly than the soil development and bedrock weathering (Watakabe and Matsushi, 2019), and their roots in most cases is not deep enough to penetrate into bedrock (Schwinning, 2010). Hypothesizing in a localized area with same ecosystem or plant species, aspect-dependent landslide initiation cannot attribute to plant roots, while may result greatly from the differences in properties of hillslope materials due to long-term differential weathering.

The aspect-dependent landslides in Frontal Colorado, USA and the Loess Plateau, China have attracted interesting focus that vegetation generates a considerable influence on the landslide distribution. In fact, the overwhelming propensity for shallow landslide initiation on south-facing hillslope in the two regions closely relates to the present-day tree density, regardless of hillslope aspect (Ebel, 2015; Rengers et al., 2016; Deng et al., 2022). In the Colorado Frontal Range, field observations proved that south-facing slopes lack thick tree cover and have an abundance of rock outcrops compared to north-facing slopes, and the soil layer would be thinner on south-facing slopes (Coe et al., 2014; Ebel et al., 2015). The apparent cohesion supplied by roots was responsible for the observed connection between landslide distribution and slope aspect (McGuire et al., 2016). In the Loess Plateau China, vegetation recovery is the major ecological measure to mitigate the sediment loss (Fu et al., 2009). Promoted soil strength and hydraulic conductivity due to strong root network may enhance the topographic initiation condition (Montgomery and Dietrich, 1994; Wang et al., 2020). Another possibility is that the north- and west-ward moving storm produced more intense rainfall on south- and east facing slope. Such assumption may be invalid if aspect-dependent landslide distribution exists in a localized catchment with given vegetation communities. In fact, the above-mentioned study highlights the effect of mechanical function of plants on landslide. If the aspect-dependent landslide exists in a localized area that are covered by same plant species and high vegetation coverage, the observed aspect-dependent landslide initiation cannot attribute to mechanical effect from plant roots.

To elucidate the observed relationship among vegetation, landslide and slope aspect, the effect from physical properties and strength of hillslope materials cannot be ignored. In the Northern part of Loess Plateau China, as well as in many other semi-arid environments, different types and densities of vegetation and soils develop on north-facing versus south-facing convergent slopes, because systematic differences in the amount of direct sunlight translate into differences in the physical and chemical weathering. North-facing convergent slopes have lower evaporation rates, retain snow cover longer in spring, and tend to hold soil moisture longer into the summer growing season. Such differences may result in local ecosystem communities in presence of trees or shrubs over grasses. South-facing slopes experience heavier and more frequent hydration, thermal expansion or freeze-thaw cycle by the day warming and night cooling, and tend to favor stronger weathering throughout the year. Such differences could result in local differences in grain component, soil strength and soil profile, which indirectly affect the landslide scale by mechanics of excessive pore water pressure dissipation and sliding surface liquefaction (Terzaghi, 1950; Sassa, 1984), and the hillslope hydrology behavior (Godt et al., 2009; Lee and Kim, 2019). Therefore, the physical properties of hillslope materials may attribute to the observed aspect-dependent landslide initiation.

2. The reviewer wants to know what exactly is your definition of north and south facing - which angle ranges (relative to North) is "allowed"? From the GoogleEarth images, there might very well also be west- and east-facing slopes. Were they excluded from the analysis?

Response: Thanks for your valuable comments.

In Section 4.1 of the result analysis, we added the definitions of south facing and north facing slopes, excluding the landslides on the east and west slopes.

In the study area, the south-facing slope is between 157.5 ° and 247.5 °, the north-facing slope ranges from 0 ° to 67.5 °, and 292.5 ° to 360 ° (0 ° is the due north). There were 71 shallow landslides on south-facing slope, while merely 20 landslides on north-facing slope.

3. The mechanisms leading to landslides are considered to some detail, including pore water dissipation, water storage and drainage, and stability fluctuations. The description of the latter is incomplete; there are equations shown for the "finite slope model" and the "infinite slope stability model", involving many parameters (such as angles) usually not easily to obtain in the field. Were these modelled by Hydrus-1D? How reliable are these estimates?

Response: Thanks for your detailed comments.

For the parameter problems in the infinite and finite slope models, the slope and area of the landslide are extracted with high-precision topographic data using GIS software, the landslide depth is measured by field survey, the physical and mechanical property parameters are measured by GDS triaxial, and the hydrological parameters are measured by Trim combined with Hydras-1D. As for the reliability of the data of

Hydrus-1D inversion, we made a supplementary explanation in Section 4.4.2 of the conclusion, and proved the reliability of the parameters through the algorithm and optimization index used by the software.

The hydraulic properties, such as Soil Water Characteristic Curve (SWCC) and Hydraulic Conductivity Function (HCF), are critical to the analysis of water flow movement and mechanical behavior unsaturated soil material. In this study, the unsaturated hydraulic property measurement adopted Transient Release and Imbibition Method (TRIM). The intelligent advantage of TRIM method lies in that it combines physical and numerical experiments. In detail, it employs the simple and reliable measurement of transient water content by electronic balance to record the signature of transient unsaturated flow, and takes advantage of the robust inverse modeling capability to simulate the physical process. The apparatus can accommodate both undisturbed and remolded samples. The results of this study were obtained by using the Hydrus-1D code with the reverse modeling option, which implemented the Levenberg-Marquardt non-linear optimization algorithm, and minimized the error between the results in test and the simulation (Wayllace and Lu, 2012). Meanwhile, in order to ensure the uniqueness of the parameters, the aforementioned algorithm repeatedly run with different initial parameter estimates, until it always converges to the same or similar results. Compare the prediction results with the function curves of water flow and time obtained from the actual experiment, so that they can be basically combined to meet certain accuracy requirements. In this experiment, the R square of the regression between the optimized predicted value and the observed value is greater than 0.99. In addition, the model constraint effect of trim under two suction increment steps is better, and the parameters obtained by inversion calculation are more accurate (Lu and Godt, 2013). Table 2 shows the soil characteristic parameters obtained by Hydrus 1-D inversion.

4. Obviously (Fig. 11), the two Fs (eqs. 8 and 9) are dynamic quantities - which of the variables on the rhs are time-dependent? At least for the finite model, the time dependence seems to be marginal, but the difference in the mean values seems to

be huge in comparison (Fig. 11 lower left panel). What is precisely the origin of this discrepancy? The lower right panel shows that for the south-facing slope, the situation is rather similar (very stable values for Fs), whereas for the north-facing, Fs varies a lot. Why is that the case, i.e. what property or variable of eq. 9 is responsible for that? The reviewer disagrees with the statement that (thus) the infinite slope model would better support the observations, since the only rationale for that is by confirming the prejudice that south-facing slopes are more prone to landslides than north-facing ones. This is circular reasoning.

Response: Thanks for your detailed comments.

First of all, we add such a paragraph to the result 4.6 when we analyze the reasons for the difference in aspect using infinite and finite slope models. The purpose of finite slope model is to verify the problem from the mechanical point of view, while the infinite slope model is to verify the problem in the aspect of slope hydrological movement, because the mechanical properties, slope scale and bedrock permeability of north-south landslides are very different.

In this study, the infinite slope model and the finite slope model are used to characterize the sensitivity of landslide triggering, so as to determine the main mechanism of overwhelm landslide probability on south-facing slope. The infinite slope model studies the transient stress changes caused by water entering the soil, emphasizing the difference of soil permeability (Lu and Likos, 2006; Lu and Godt, 2013). The finite slope model focuses on the cohesion of the base surface and lateral periphery of the ground landslide source body, as well as the influence of the lateral additional cohesion provided by the vegetation root system for the landslide (Schmidt et al., 2001; Dai et al., 2022).

Secondly, in the two models, the time related parameter is saturation, which is calculated according to the actual monitored water content. The small correlation between the curve and time of the finite slope model may be due to the fact that the quantitative sliding area is considered in the calculation of the sliding force and resistance in the model, and the increment and fluctuation of the curve are reduced in the calculation; Secondly, the large difference between the north and south slopes in the finite model mainly depends on the cohesion. The cohesion of the sliding layer soil on the sunny slope is twice that on the shady slope, so the stability of the sunny slope is higher. In the infinite model, the stability calculation of yin and yang slopes brings in the intake value and the parameters related to the aperture, such as α And n, these two parameters will affect the height and amplitude of the curve, mainly acting on the change of the suction stress of the slope during rainfall, which can characterize the movement of water through the pores after entering the soil mass, and may be the result of the joint action of macropores and matrix pores, which is the future research direction. This study is mainly to verify that the hydrological movement of the slope is the main reason affecting the difference of slope aspect by comparing the stability analysis results with the actual landslide density. In section 4.6 of the results, we added a paragraph describing the analysis results of the two models.

In all, the results of finite slope model reveal that the south-facing slope has relatively high stability, which mainly attribute to the fact that the effective cohesion of hillslope materials on the south-facing slope is stronger than that on the north-facing slope, even though the basal area of the landslide is more than twice. However, this result is inconsistent with the overwhelm landslide density on south-facing slope. Results of infinite slope model, considering the soil characteristic parameters of the soil moisture characteristic curve, reveal that the north-facing slope shows higher stability. In the analysis of finite and infinite models, the stability fluctuation amplitude of the south-facing hillslope is smaller than that of the north-facing hillslope, indicating that the water movement in the south-facing slope is less active than that in the north-facing slope. Therefore, in this study area, the change of soil stress is more sensitive to the slope stability than the change of root soil cohesion. It is verified that the change of soil permeability caused by differential weathering of bedrock could be responsible for the aspect-dependent landslide initiation in the study area.

5. However, the fundamental problem of the paper is that there is only a single site investigated, where landslides have occurred both at north-facing as well as south-

facing slopes. The statistics of that particular location shows that more landslides for south-facing slopes have been recorded: 71 versus 20 - this is probably the result of a field survey in the area, but the time span over which these happend should be mentioned as well, if known. The whole area is densely tree covered, with a larch species dominating. In the GoogleEarth image, it seems that there are a lot of terraces surrounding the local peaks - is that due to management? If so, what was done there? This striking feature is not mentioned in the manuscript but could of course impact on landslide probability (either way).

Response: Thanks for your valuable comments.

In this study, all landslides were generated in July 2013. We purchased two high-precision remote sensing images in 2013 and 2010 to extract the landslides in the study area, and obtained the quantitative characteristics of landslides. As for the problem of terraces in the study area, we did not express it clearly when we discussed the study area before. Our study area is only in the Majiaba watershed in the north of Niangniangba, which is mainly mountainous. Terraces will only appear in the east and south of Niangniangba. The landslides we studied are on the slopes of the selected watershed, which can exclude the impact of man-made changes in land use types on landslides in the study area. Finally, we added the description of Majiaba watershed in the overview of the study area, and explained the reason for choosing it as the research object.

The study area is in the mountain region of Majiaba village in the northeast of Niangniangba town, Tianshui City, Gansu Province, Central China. It is also close to the dividing crest of the Yellow River and Yangtze River, and in the eastern part of the Loess Plateau. Majority of the hillslope are underlain by slate; the stratigraphic units of granite, sandstone, and mudstone account for a relatively smaller area. This area in semi-humid climate region and has four distinctive seasons. The annual precipitation is approximately 491.6 mm and mostly falls during June and August. One branch fault of the Tianshui-Lanzhou fault system runs through the area and has no rupture records for the last few decades.

The shallow landslides in the study area and nearby surroundings were triggered by the prolonged antecedent precipitation during 1 to 24 July and the intensive rainstorm on 25 July 2013 (Yu et al., 2014; Guo et al., 2015). Previous studies found that majority of shallow landslides in the whole storm-spanned mountain area have gradient of 20–25°, locate on south-facing slopes and in areas with sparse vegetation (Li et al., 2021). Besides, the strong root network may promote the hydraulic conductivity of soil-root composite and the landslide initiation condition of upslope contributing area-slope gradient, according to the landslide cases in the *Larix Kaemphferi* and *Pinus tabuleaformis* forest (Dai et al., 2022). In this work, the three small catchment areas in Majiaba watershed are underlain by granite unit. The total area is 0.88 km^2 with vegetation coverage rate of over 90% (Fig. 1). The relative relief is about 200 m and the mean hillslope gradient is 37°. The reasons why choose the three catchments lie in that the main plant species on the south- and north-facing slope is *Larix Kaemphferi*, which commonly have highly-developed lateral roots with depth < 0.4 m. However, landslides in the three catchments still exhibit overwhelm propensity on south-facing slope over north-facing slope. Such a finding differentiates from the results in Frontal Colorado, USA, and Central Loess Plateau where landslides commonly occur in sparsely vegetated area. Furthermore, the works of Li et al. (2021) merely addressed the relationship between landslide probability and vegetation coverage in a regional scale, while neglected the importance of the properties of hillslope materials in a localized scale. Therefore, we hypothesize that such observation in the study area may not result from the mechanical effect of plant roots, but from distinctive physical properties and strength of hillslope materials due to differential weathering.

6. However, how could an investigation at one particular area say something conclusive about 3aspect-dependent landslide probabilities in general?

Response: Thanks for your valuable comments.

For the Niangniangba area, previous studies on the macro regional scale found that the landslide in the Niangniangba area has different slope directions, which is characterized by a large number and area of landslides on the south slope and a small number and area of landslides on the north slope. In order to analyze the triggering mechanism of landslide at the micro scale, we conducted a detailed landslide survey in the mountainous areas in the north of Niangniangba, such as Majiaba, Shangyao, Beiyugou and other watersheds in August 2021, and selected representative sites for sensor monitoring and sampling analysis. This study is mainly aimed at specific watersheds. From the perspective of mechanics and hydrology, it explains the mechanism of landslide generation, provides some research methods and ideas, and reveals that the hydraulic characteristics of rock and soil mass are also a factor that cannot be underestimated compared with the vegetation factors.

7. In that regard, the paper seems to be way too ambitious. To do justice to the paper, systematic differences between north- and south-facing slopes are investigated to some detail. The slopes are rather steep but not different between S- and N-slopes (Fig. 3 left panel); grain diameter distributions are rather similar (Fig. 5); the physical properties reveal some differences, in particular for the saturated hydraulic conductivity, which of course can imply different water routing during and after rainfall events. On the other hand, in the unsaturated domain, it is not obvious that there are any differences in the pF curves (Fig. 8); they look strikingly similar for the two slope aspects. The shear tests (Fig. 6), on the other hand, seem to indicate that the two slope types have different pore water pressure behaviour (NB the reviewer wonders what the legend of that figure ("Time (10-sec)") would mean? Do you intend to say that the time axis is in logarithmic units (to base 10)? It doesn't seem to make sense).

Response: Thanks for your detailed comments.

In terms of gradient, the average gradient of landslide initiation on the south and north slopes does not differ much, but considering the catchment area, the critical condition for spatial initiation on the south slope is lower than that on the north slope. However, the shear strength and permeability of soil are the main influencing factors. In terms of particle size distribution, the south slope shows advantages in fine particles.

The soil water characteristic curve in Figure 8 shows that the soil on the south slope has more hysteresis effect than that on the north slope. In the pore water pressure characteristics, "10-sec" is the time interval for the software to automatically read data, which has no special meaning.

We performed CU tests to obtain the effective cohesion, effective internal friction angle, and the pore pressure water dissipation curves. The soil sampling, with diameter 50 mm and height of 100 mm, were firstly saturated in a vacuum pump, then consolidated in the chamber of GDS apparatus by 50, 100, 150, and 200 kPa confining pressure and 10 kPa backpressure. During each test, the shearing rate set as 0.1 mm/min, the device automatically records one data every 10s.

8. However, cause and effect are totally unclear here: are these differences induced by the different aspects, or just geological properties of the area, or random variation due to small sample sizes?.

Response: Thanks for your valuable comments.

The main reason for the difference of slope direction in the study area is the differential weathering of bedrock caused by solar radiation, which makes the rock and soil mass show differences in hydraulic properties. Then, the problem is explained from the aspects of shear strength, pore water pressure, unsaturated permeability and stability. In view of the randomness of the samples, we added a paragraph of discussion in Section 3.2 Field Sampling Survey Method, which shows that we have done a certain amount of actual investigation work in the field, and obtained that the soil mass in this area does have obvious weathering differences. At the same time, we added a paragraph of discussion in the discussion link, which shows that our samples are representative without randomness, Secondly, differential weathering of bedrock is also the most obvious geological feature in this area.

To investigate the hillslope hydrology on the south- and north-facing slope, the Frequency Domain Reflectometry (FDR) soil moisture sensors were used in this work to record volumetric water content. To avoid the randomness of data caused by natural factors such as terrain and vegetation, a total of 16 shallow landslides were investigated, to excavate soil profiles and take undisturbed soil sampling. Then, the sensors were implemented at depths of 30cm, 70cm, and 110cm on south- and north-facing slope, to monitor the volumetric water content during the rainy season 2021.

Additionally, this work mainly highlights the role of hydraulic properties on the landslide occurrence. Though the south- and north-facing slope are merely underlain by granite, the physical properties of hillslope materials, such as the excessive pore water pressure, strength of sliding mass, soil water storage and leakage, differentiates a lot. Such a finding cannot be random because the study area is selected on condition that it is far from the northern and eastern area where local soils are mainly from Loess deposits, and the study area of Li et al (2021) and Dai (2022), where the bedrock underneath differs greatly.

9. A technical problem is that the language quality has to be improved. There are a non-negligible number of grammar errors and incomplete sentences which inhibits comprehensibility at times. Before resubmission, this issue should be carefully addressed.

Response: Thanks for your suggestions.

We try our best to improve the written English during the first revision. Also, we want find help from someone who can polish our manuscript.

10. Summarizing, the observational investigation for the selected sites is profound, and the processes and phenomena considered are numerous. However, the presentation is incomplete and in part difficult to follow, and most importantly, the conclusions drawn from this small field study seem to be too far-fetched. The paper deserves a major revision.

Response: Thanks for your suggestions.

Thanks for your admission on our works. We did make great works to explain the aspect-dependent landslide from a new perspective of hydraulic conductivity, other than from plant roots.

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Detailed Response to the Reviewer Comments

Thank you, Tammo Steenhuis.

Thanks for your constructive comments, helping to improve the quality of our manuscript. We are sorry for delaying answer the valuable comments because we are asked to stay at home for almost 2 months, due to the Coronavirus policy in Beijing and Beijing Forestry University. In such a condition, the team members read the comments and revised carefully after we are permitted to enter the office. With full consideration of the reviewers' suggestions, the manuscript has been carefully reshaped and we made point-by-point responses to address your comments.

Besides, the editor Jorge Isidoro and reviewer 1 suggest the written English should be improved by a professional editing service. Meanwhile, an additional effort and final revision of the manuscript should be made to improve the readability. In the following, we answer all comments (set in black fonts) and give response (set in blue fonts). Quotes of the revision are set using a red font.

Reviewer #2:

The authors present a complicated explanation for the greater number of bank failures on the south slope than on the north slope.

Response: Thanks for the appreciative comments.

I am not sure if the analysis is correct since hillslope stability is not my field. However, I know that when the soil becomes saturated, the hillslope could fail, given that roots do not keep it in place. Based on this simple principle, we can explain, based on the data given in this manuscript, the difference between the north and south-facing slopes in simple terms as follows:

1. The conductivity of the subsoil is greater on the north-facing slope than on the south-facing slope. Thus, the north-facing slope drained faster than the south-facing

slope, and as shown in Figure 9, the soil on the north-facing slope does not saturate. In contrast, on the south-facing slope, the rainfall rate at some point is greater than the water that can be carried off laterally, and the soil saturates, as shown in figure 9. The saturation causes the soil strength to decrease, and failure occurs. Hence more failures on the south slope than on the north-facing slope.

Response: Thanks for your detailed comments.

The drainage ability of hillslope materials is merely one of the factors. In the study area, the aspect-dependent landslide initiation may result mainly from the hydraulic conductivity, which indirectly attribute to the difference weathering. However, shallow landslides result from multiple factors, including the strength of hillslope materials, hydraulic conductivity, slope profile, and topographic factors. As the hydraulic conductivity plays a more important role on the landslide distribution, we mainly examined its role on the landslide initiation. However, the stability analysis results of the two models combines multiple factors, including the suction stress, cohesion, friction, topographic slope, failure depth. Importantly, the excessive pore water pressure dissipation strongly proves the drainage ability of hillslope materials. Therefore, excessive pore water pressure, together with the stability analysis greatly improve the understanding and elucidation of the reason about aspect-dependent landslide initiation.

2. Figure 9 is hardly discussed in the manuscript. It is likely the most significant finding as it shows that the oil becomes saturated on the south slope while not on the north slope.

Response: Thanks for your valuable comments.

First, thanks for your important reminds here and we may neglect your finding because we mainly focus on the water storage and leakage process based on the observed soil moisture. Secondly, figure 9 merely shows the volumetric water content during the observation stage, and mainly supports the results of figure. 10. In the revised manuscript, we added new contents according to your suggestions:

In comparison, it is likely the most significant finding as it shows that the soil becomes nearly saturated on the south slope while not on the north slope. This implies that the soil water on the south-facing slope is difficult to drain because of more fine grains and the slow pore water pressure dissipation. Besides, the stable soil moisture of layers No. 2 and 3 for both slopes may attribute to long dry seasons in the study area, and the daily rainfall amount > 30 mm on July 9 and 23 resulted in soil moisture increase for all slope layers.

3. On line 377, the authors write that "the saturated hydraulic conductivities by variable-head permeameter and TRIM methods coincide with each other, which together prove that the soil mass on north-facing slope has a relatively larger water infiltration. The amount of water infiltrated on a slope depends on the amount of rainfall and not the conductivity as long as it is greater than the rainfall rate. Moreover, laboratory-derived conductivity is a poor predictor for field hydraulic conductivity in the topsoil where plant roots and animal life provide vertical preferential flow paths.

Response: Thanks for your detailed comments.

Your comments here highlighted the importance of in-situ measurements on the hydraulic conductivity. We also want to carry out the field hydraulic conductivity test, which would be more reliable than the laboratory-derived conductivity. However, it is very dangerous to carry out field tests because there were no human beings there after the extreme events in 2013. However, the Test of TRIM method were carried out in the laboratory. Besides, it is time-consuming to carry out in-situ measurements because the tests of preferential flow path must consider multiple sites. Therefore, we choose to monitoring the soil moisture to check the soil water storage and leakage. Additionally, you can see from figure 9 that the preferential flows are in form of sequential flow, not the nonsequential flow. In future, if possible, we may continue to examine the preferential flow path and analysis the effect on the landslide initiation.

4. As I indicated before, I leave it up to the experts if the hillslope analysis is correct or not. It seems too complicated for the little information that is available on this

site. The fact that the soil strength decreases greatly at the time the soil becomes saturated is important and is not well addressed. In addition, the fact that soil saturates should be stressed in the manuscript that claims to be a hydrologic analysis.

Response: Thanks for your valuable comments.

There is no doubt that the hillslope stability analysis is correct in this work. On basis of suction stress definition in the Soil mechanics for unsaturated soils, the soil strength is from two parts: the first part derives from the particle connection, and the second part comes from the capillary force depending on the soil moisture. If the soil becomes nearly saturated, the soil strength will reduce greatly because the matrix suction disappears. The reason why we choose two stability models to analyze the hillslope stability fluctuation lie in that the role of hydrologic properties on the aspect-dependent landslide initiation is more important than other factors. Therefore, some hydraulic properties, such as the hillslope material properties, unsaturated conductivity, excessive pore water pressure, soil water storage and leakage, must the clarified in advance to support the stability analysis.