Response to the comments of Anonymous Referee #3 for nhess-2019-349

Answers to Technical items for which revision is required --- '*A multivariate statistical method for susceptibility analysis of the debris flow in Southwest China*'

The authors are grateful for the reviewer's comments and suggestions. The manuscript has been revised and each point of the reviewer's comments has been incorporated and addressed. Your comments have greatly improved the quality of this paper and we hope the revised manuscript will be of suitable standard to be accepted for publication in your journal. The main corrections in the manuscript and the responses to the reviewer's comments are as follows:

This paper introduces an empirical model for the susceptibility prediction of debris flows in Southwest China. Nine indexes are chosen to construct a factor index system and to evaluate the susceptibility of debris flow. With the model, 70 typical debris flow gullies distributed along the Brahmaputra River, Nujiang River, Yalong River, Dadu River, and Ming River as statistical samples are assessed respectively. 10 debris flow gullies on the upstream of the Dadu River are applied to verify the reliability of the proposed model which suggest a high accuracy of 90% for the statistical model. The paper is general well organized and based on plenty of investigated information. However, there are still many unclear and inexact expressions.

Answer: Thank you very much for your positive comment on our research. We have studied your comments carefully and made corresponding revisions as required.

1. In abstract line 14-15, the statement "At present, the susceptibility analysis models of the debris flow in Southwest China is mainly based on qualitative methods. Little quantitative prediction model is found in the literatures." is not true. There have been many research works in the area after "the shock". The author should refer and comment the previous study objectively.

Answer: Thank you for this comment. We delete this sentence in the abstract and refer the previous study objectively in the Introduction section.

"*In the literature, many models for the debris flow risk prediction in this area have been proposed. For example, Xu et al. (2012) assess the debris flow susceptibility based on information value model and Geographic Information System (GIS) in Sichuan, China. Wang et al. (2016) adopted a self-organizing map method to analyze the susceptibilities of debris flows at the Wudongde Damsite in southwest China. Li et al. (2017) carried out a susceptibility analysis on debris flows also in the Wudongde dam area using the fuzzy C-means algorithm (FCM). Recently, Liu et al. (2018) presented a comprehensive risk assessment model based on semi-quantitative methods to quantify the risk level of each zone in Southwest China. Di et al. (2019) developed a gradient boosting machine (GBM) to predict the susceptibilities of debris flows in Southwest China. Wu et al. (2020) implemented logistical regression models to identify the areas that are susceptible to debris flow formations in Sichuan Province, China. Through the above researches, some promising results have been achieved concerning the susceptibility analysis of the debris flows in Southwest China.*" (Page 3, Lines 68-78)

Wang, Q., Kong, Y., Zhang, W., Chen, J., Xu, P., Li, H., Xue, y., Yuan, X., Zhan J., Zhu, Y. Regional debris flow susceptibility analysis based on principal component analysis and self-organizing map: a case study in Southwest China. Arabian Journal of Geosciences, 9(18), 718, 2016.

Li, Y., Wang, H., Chen, J., Shang, Y.: Debris flow susceptibility assessment in the Wudongde Dam area, China based on rock engineering system and fuzzy C-means algorithm. Water, 9(9), 669, 2017.

Liu, G., Dai, E., Xu, X., Wu, W., Xiang, A.: Quantitative assessment of regional debris-flow risk: a case study in Southwest China. Sustainability, 10(7), 2223, 2018.

Di, B. F., Zhang, H. Y., Liu, Y. Y., Li, J. R., Chen, N. S., Stamatopoulos, C.A., Luo, Y.Z., Zhan, Y.: Assessing Susceptibility of Debris Flow in Southwest China Using Gradient Boosting Machine. Scientific Reports, 9: 12532, 2019.

Wu, S., Chen, J., Xu, C., Zhou, W., Yao, L., Yue, W., Cui, Z.: Susceptibility Assessments and Validations of Debris-Flow Events in Meizoseismal Areas: Case Study in China's Longxi River Watershed. Natural Hazards Review, 21(1), 05019005, 2020.

2. In abstract line 21, what is "the quantification theory type I", it never explained in the content.

Answer: Thank you for the comment. We add some explanations about "the quantification theory type I" in the manuscript: "*Hayashi's quantification theory is a well-known multivariate statistical method developed by Hayashi (1961). The quantification theory type I applies multiple linear regression methods, which can simultaneously process qualitative and quantitative variables, and evaluate the weight of each variable. Therefore, it is widely used in various fields (Matsumura 2004; Ishihara et al. 2008; Inoue et al. 2009; Shen and Chen, 2018). In this method, the qualitative and quantitative variables could be mutually transformed based on a reasonable principle. Therefore, this method has very good applicability to process the quantitative and qualitative influencing factors of debris flow risk.*" (Pages 6-7, Lines 152-158)

Matsumura, T.: Analysis of ovipositional environment using Quantification Theory Type I: the case of the butterfly, Luehdorfia puziloi inexpecta (Papilionidae). Journal of Insect Conservation, 8(1), 59–67, 2004.

Ishihara, S., Nagamachi, M., Ishihara, K.: Analyzing Kansei and design elements relations with PLS. In 10th QMOD Conference. Quality Management and Organiqatinal Development. Our Dreams of Excellence; 18–20 June; 2007 in Helsingborg; Sweden (No. 026). Linköping University Electronic Press.

Inoue H., Tabata H., Tsuji H.: Emotion color combination models using the quantification theory type I and its application to uniform color combination. Transactions of Japan Society of Kansei Engineering, 8(3): 775–781, 2009. (in Japanese)

Shen KS, Chen, KH.: Exploring the Critical Appeal of Mobility-Augmented Reality Games. In: International Conference on Kansei Engineering & Emotion Research. Springer, Singapore, 451–459, 2018.

3. Line 18-19 and those then after, "longitudinal grade" and "valley slope orientation" are not exact the meaning, maybe "longitudinal gradient" and "valley orientation"

Answer: We agree with this comment. The term "*longitudinal grade*" is replaced by "*longitudinal gradient*", and the term "*valley slope orientation*" is replaced by "*valley orientation*" in the manuscript.

4. Line 77, "Study area characteristics of debris flow", not clearly expressed, maybe "Characteristics of the debris flows in the study area"

Answer: We agree with this comment and replaced "*Study area characteristics of debris flow*" with "*Characteristics of the debris flows in the study area*" in the manuscript. (Page 4, Line 86)

5. Line 122, in 3.3, it just mentioned "Considerable resources are invested in drilling and geophysical prospecting", but there is no any more information and results provided.

Answer: According to this comment, the information and results of the drilling and geophysical prospecting are provided in the manuscript:

"*The geologic condition in the active debris flow gullies in Southwest China is very complicated. To investigate the material composition and the thickness of the deposit area, the geological drilling was conducted in the active debris flow gullies along the Dadu River, Yalong River, Yaluzangbo River, and Minjiang River. The drilling information, such as the drilling location, drilling depth, and the soil characteristics are provided in Table 2.*" (Page 6, Lines 141-145)

Table 2 Information and results of the geological drilling in the study area

No.	***River***	***Debirs flow gully***	***Geological coordinates***	***Drilling depth (m)***	***Soil characteristics***
1	*Yalong River*	*Reshui Gully*	*101°16'42"E 28°24'08"N*	*15*	*The lithology is mainly metamorphic sandstone and carbonaceous slate, with a small amount of quartzite. The percentage of boulder and gravel is about 40%, which is slightly angular. Their particle sizes are 40-60cm and 4-9cm, respectively. The rest material is silty clay with medium dense. The cementation state of the soil material in this area is good.*
2	*Yalong River*	*Reshui Gully*	*101°16'44"E 28°24'10"N*	*22*	
3	*Yalong River*	*Reshui Gully*	*101°16'45"E 28°24'12"N*	*26*	
4	*Yalong River*	*Shangtian Gully*	*101°16'26"E 28°24'08"N*	*21*	*The lithology is gravel soil with medium dense. The percentage of gravel and coarse sand are 43% and 20%, and the rest of the material is clay. The average thickness of the deposit in this area is about 19.0m.*
5	*Yalong River*	*Shangtian Gully*	*101°16'29"E 28°24'11"N*	*17*	
6	*Dadu River*	*Shuikazi Gully*	*101°52'07"E 31°03'38"N*	*31*	*The thickness of upper layer of the deposit is about 1.5 m, and the material is weak cemented silty clay with a small amount of gravel. The thickness of middle layer is about 2.0 m, the material is clay mixed with gravel, containing a small amount of boulder. The particle size of the gravel, breccia, and boulder are 2-3 cm, 10 cm, and 40 cm, respectively. The soil content in this layer is up to 70%. The lower layer is mainly composed of gravel and sand, and the particle size is relatively uniform, generally 5-8 cm. The roundness of the particles is good, and the content of fine particles is low.*
7	*Dadu River*	*Shuikazi Gully*	*101°52'09"E 31°03'39"N*	*36*	
8	*Dadu River*	*Shuikazi Gully*	*101°52'11"E 31°03'41"N*	*35*	
9	*Dadu River*	*Kaka Gully*	*101°52'12"E 31°00'11"N*	*21*	*The lithology is mainly mica quartz schist, which is slightly angular, grayish yellow, dry, and medium dense. The particle size of the boulder is 20-40 cm, accounting for about 40%. The boulder layer in this gully is mainly filled with silt and a small amount of gravel.*
10	*Dadu River*	*Kaka Gully*	*101°52'14"E 31°00'15"N*	*19*	
11	*Yarlung Zangbo River*	*Menda Gully*	*92°25'12"E 29°15'22"N*	*22*	*The deposit in this area is mainly composed of gravelly soil mixed with boulder. The average particle size of the gravels is 15-20 cm, accounting for about 40%. The average particle size of block stone is about 40-60 cm, accounting for about 10%-20%. In addition, there are some sporadic boulders with the average particle size of 3-4m.*
12	*Yarlung Zangbo River*	*Menda Gully*	*92°25'11"E 29°15'23"N*	*26*	

13	*Yarlung Zangbo River*	*Menda Gully*	*92°25'13"E 29°15'24"N*	*29*	
14	*Yarlung Zangbo River*	*Zhuangnan Gully*	*92°24'23"E 29°15'39"N*	*16*	*The material is mainly composed of dense gravelly soil and a small amount of silt. The gravels with the average particle size of 30-60 cm account for about 30%. The gravels with the average particle size of 15 cm account for about 10%. The rest is breccia soil, which has poor sorting performance and obvious miscellaneous accumulation characteristics.*
15	*Yarlung Zangbo River*	*Zhuangnan Gully*	*92°24'24"E 29°15'41"N*	*11*	
16	*Yarlung Zangbo River*	*Zhuangnan Gully*	*92°24'21"E 29°15'42"N*	*17*	
17	*Minjiang River*	*Banzi Gully*	*103°31'49"E 31°24'25"N*	*18*	*The deposit in this area is mainly composed of brown yellow gravel soil, which contains 10% cobble, 45% gravels, and 20% coarse sand, and the rest is clay.*
18	*Minjiang River*	*Banzi Gully*	*103°31'51"E 31°24'27"N*	*24*	
19	*Minjiang River*	*Chutou Gully*	*103°29'12"E 31°20'21"N*	*14*	*The deposit zone in this area is 150 m long and 100 m wide. The soil material is medium dense, which contains 30% boulder and 70% gravelly soil.*
20	*Minjiang River*	*Chutou Gully*	*103°29'13"E 31°20'22"N*	*17*	
21	*Minjiang River*	*Chutou Gully*	*103°29'14"E 31°20'25"N*	*13*	

6. Line 178-180 and 190-193, same meaning reappears in very close distance, the sentence is also tedious.

Answer: According to this comment, we delete Lines 190-193, and modify the sentence in Lines 178-180.

"*Based on the statistical analysis on the debris flows occurred in Southwest China, the susceptibility values are classified into three categories in the proposed model:*

$$\begin{cases} Y < 1.5 & \text{Low susceptibility} \\ 1.5 \le Y < 2.5 & \text{Medium susceptibility} \\ Y \le 2.5 & \text{High susceptibility} \end{cases} \qquad (6)$$"

(Page 9, Lines 202-204)

7. Line 209, "trend" is not a professional expression, should be "strike".

Answer: We agree with this comment. "*trend*" is replaced by "*strike*" in the manuscript. (Page 10, Line 231)