Response to the comments of Anonymous Referee #2 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 manuscript presents a multivariate statistical model to predict the susceptibility of the debris flows in Southwest China. According to the topography and geomorphology characteristics in the study area, nine indexes were used to construct a factor index system of the statistical model. Then, 70 typical debris flow gullies in the study area were investigated as statistical samples to generate the model. 10 debris flow gullies on the upstream of the Dadu River were analyzed to verify the reliability of the statistical model. The results showed that the model has a satisfied prediction accuracy. In general, the topic of the manuscript is interesting, the methodology, results and conclusions are presented in a clear way. I recommend publication of the paper after addressing the following comments.

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. Section 2 describes the study areas of this work. Some pictures of the typical debris flow in this area are suggested to be provided.

Answer: Thank you for your suggestion. Some pictures of the typical debris flows in the study area are provided in Figure 2.

Fig.2 Typical debris flows in the study area. a) Morphology of the Xianwei Gully along the Yalong River; b) Moraine at the source of the Jiuzhui gully along the Brahmaputra; c) Loose material in the Jiaer gully along the Yalong River; d) Gravelly

soil mixed with boulder in Sezu gully along the Dadu River.

2. As stated in the Methodology section, the authors carried out a series of bulk density tests, screening tests, drilling and geophysical prospecting. This part should be described in more detail, and the results of these tests should be provided.

Answer: We agree with this comment. This part is described in detail.

"*Bulk density tests and soil screening tests are carried out in the 70 debris flow deposit areas. Figure 3 shows the results of the bulk density tests. The bulk densities of the soil material in the debris flow deposits are mainly between 1.3 g/cm^3-1.8 g/cm^3, and the average bulk density is about 1.48 g/cm^3. The results of the screening test show that the material composition in the deposit zone is mainly composed of block gravel mixed soil, the content of the block gravel is 30-50%, the content of silt and clay is about 20-40%, and the rest of the deposit material is breccia. The reason for the high content of coarse stone soil is that the collapse phenomenon is quite common due to the active crustal movement in the study area.*" (Pages 6, Lines 133-139)

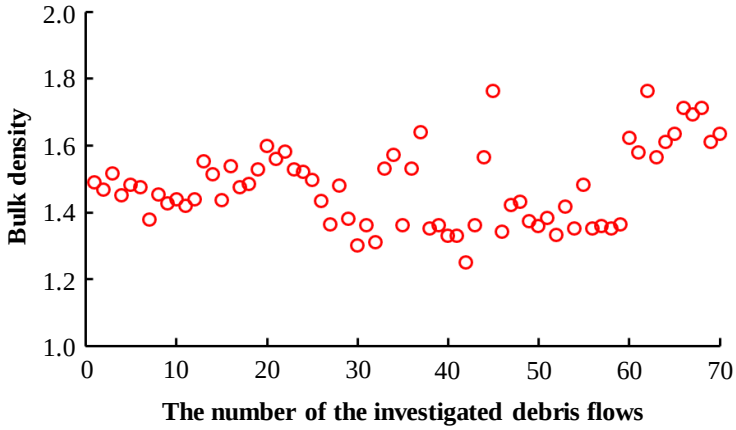

Fig. 3 Density characteristics of the debris flow deposit in the study area.

"*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*

5	Yalong River	Shangtian Gully	101°16'29"E 28°24'11"N	17	material is clay. The average thickness of the deposit in this area is about 19.0m.
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*	

3. Line 178-180: how was the criterion determined? why 1.5?

Answer: The thresholds 1.5 and 2.5 are determined based on the statistical analysis on the debris flows occurred in Southwest China. It is found that the debris flows are very activity when the susceptibility value is larger than 2.5, and the little debris flow occurs when the susceptibility value is lower than 1.5. We explain this point in the manuscript.

"*In Eq. 5, Y is the susceptibility for the debris flow, and the meanings of* x_{11}, x_{12}, x_{13} *and other indexes are detailed in Table 4. 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:*

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

(Page 9, Lines 202-204)

4. Line 188-189: How to obtain the "actual values"? Please give more detail.

Answer: Thank you for this comment. We replace the term "*actual values*" with "*actual susceptibility*" in the manuscript (Line 213). The actual susceptibility of debris flows could be determined based on the "Engineering investigation code for debris flow prevention and control of China" based on the debris flow frequency in the study area.

5. Section 5 shows the validation of the model. This part should be presented in detail. For example, what does the R^2 mean in Table 5? How to calculate the self-test coincidence rate in Table 6? How to define the residual error in Figure 3?

Answer: Thank you for this comment. We add some explanations in the manuscript.

"R^2 *is the fitting degree, which is widely used to evaluate the accuracy of prediction models. As shown in the Table 7, the fitting degree of the proposed model is 71.8%, which shows that this model can precisely predict the susceptibility of debris flows in Southwest China.*" (Page 9, Lines 208-210)

"*In this study, self-test coincidence rate is defined as the ratio of the predicted result to the actual susceptibility. As shown in Fig. 4, the predicted values of debris-flow susceptibility are graded. For the calculated results listed in Table 8, the prediction accuracy for the low susceptibility, medium susceptibility, and high susceptibility debris flows are 78.5%, 92.3%, 82.0%, respectively, which indicates that the proposed model can predict the debris-flow susceptibility well.*" (Page 9, Lines 214-218)

"*Residual error is the difference between a group of values observed and their arithmetical mean. As shown in Figure 5, the residual error of the model mainly fluctuates between ± 0.45, which indicates that the regression line can fit the field value well, and the residual frequency is approximately close to the normal distribution.*" (Page 9, Lines 220-223)

6. The susceptibilities of 10 typical debris flow gullies on the upstream of the Dadu River are calculated to verify the proposed statistical model. It is suggested to show some pictures about these debris flow sites.

Answer: Thank you for your suggestion. We add some pictures of the debris flow gullies in the manuscript.

Fig.7 Typical characteristics of Danba section in upper reaches of Dadu River. a) Geomorphology of Bawang Gully; b) Loose deposits in the Mueryue Gully; c) Loose deposits on the trench bed of Shuikazi Gully; d) Abundant source material in the Qiongshan Gully.

7. The Fig.4 should be more informative, or it is suggested to be combined with Fig.5. Besides, the quality of the figures should be improved, such as Figure 2, Figure 3, and Figure 4.

Answer: According to this comment, we improve the Figure 2, Figure 3 and combine Figure 4 with Figure 5.

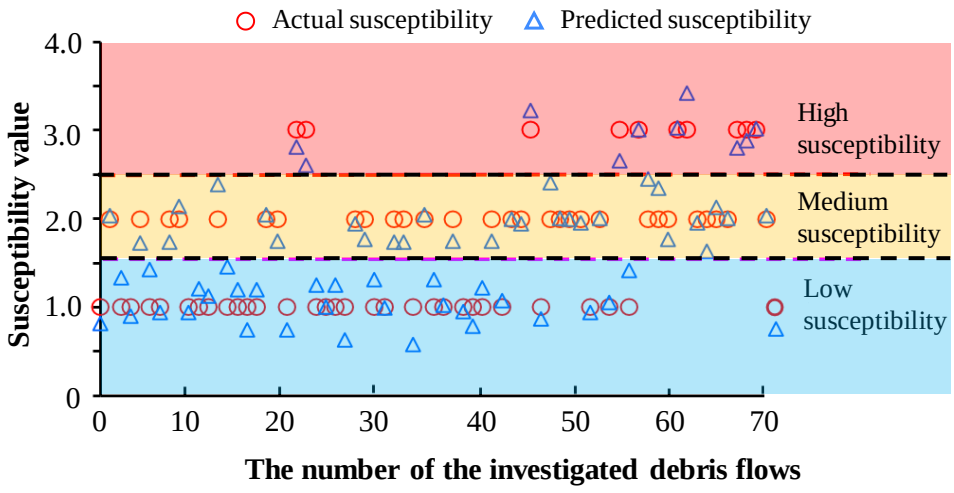

Fig.4 Comparison of actual susceptibility and predicted actual susceptibility.

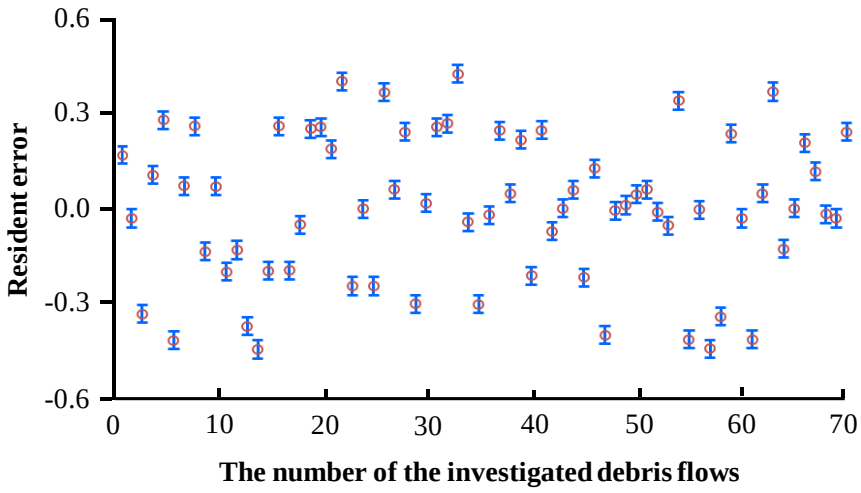

Fig.5 Residual distribution in the regression model of debris flow susceptibility.

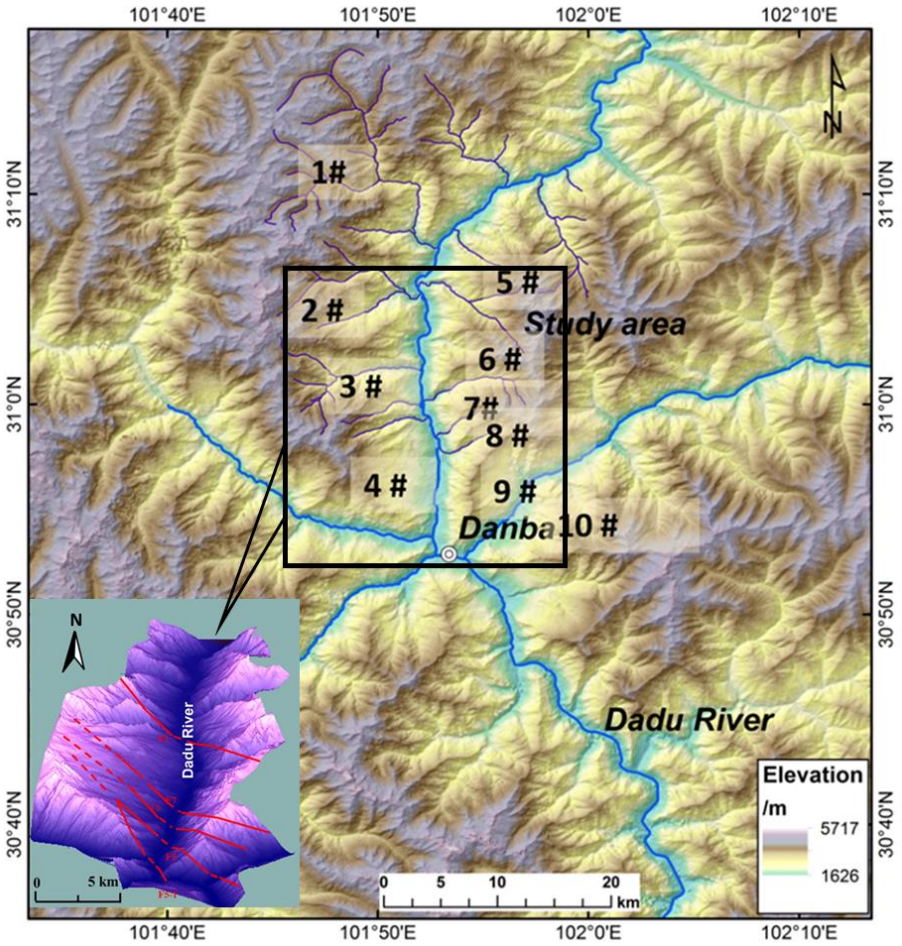

Fig.6 Distribution of debris flow gullies in Dadu river basin.