Response to the comments of Anonymous Referee #1 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:

1. Geological drilling was conducted in the active debris flow gullies. The detail information about the drillings conducted in this work should be provided, such as the drilling location, the drilling results.

Answer: Thanks for your suggestion. To find out 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 and the corresponding soil characteristics 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

<table>
<tr><th>No.</th><th>River</th><th>Debirs flow gully</th><th>Geological coordinates</th><th>Drilling depth (m)</th><th>Soil characteristics</th></tr>
<tr><td>1</td><td>Yalong River</td><td>Reshui Gully</td><td>101°16'42"E 28°24'08"N</td><td>15</td><td rowspan="3">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.</td></tr>
<tr><td>2</td><td>Yalong River</td><td>Reshui Gully</td><td>101°16'44"E 28°24'10"N</td><td>22</td></tr>
<tr><td>3</td><td>Yalong River</td><td>Reshui Gully</td><td>101°16'45"E 28°24'12"N</td><td>26</td></tr>
<tr><td>4</td><td>Yalong River</td><td>Shangtian Gully</td><td>101°16'26"E 28°24'08"N</td><td>21</td><td rowspan="2">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.</td></tr>
<tr><td>5</td><td>Yalong River</td><td>Shangtian Gully</td><td>101°16'29"E 28°24'11"N</td><td>17</td></tr>
<tr><td>6</td><td>Dadu River</td><td>Shuikazi Gully</td><td>101°52'07"E 31°03'38"N</td><td>31</td><td rowspan="2">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</td></tr>
<tr><td>7</td><td>Dadu River</td><td>Shuikazi Gully</td><td>101°52'09"E 31°03'39"N</td><td>36</td></tr>
</table>

8	Dadu River	Shuikazi Gully	101°52'11"E 31°03'41"N	35	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.
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	

2. Table 2 lists nine assessment indexes used in the proposed statistical model. The reason why to select these indexes to evaluate the susceptibility of debris flow gullies should be clarified.

Answer: We agree with this comment. The reason to select these nine indexes has been explained in the manuscript as:

"*There are many factors that affect the debris flow formation and development. From the perspective of source material of the debris flows, the main influence factors are catchment area, loose material position and loose material reserves. The antecedent precipitation and H1p rainfall intensity are the main generate conditions of debris flows. Besides, the catchment morphology, longitudinal gradient, average gradient of slope on both sides of the gully, and valley orientation are the main* *factors to affect the development of debris flows. Therefore, the above nine indexes (listed in Table 3) are selected in this study to assess the susceptibility of debris flows.*" (Page 8, Lines 179-185)

3. In Table 2, the value of antecedent precipitation x_{83} should be "Fully" rather than "Middle". How to define the antecedent precipitation is "Inadequacy, Middle, or Fully"?

Answer: Thank you for this comment. The classification standard of the antecedent precipitation is explained in the manuscript as:

"*The antecedent precipitation can reduce the soil shear strength, and has an important influence on the formation and the scale of debris flows (Shieh et al. 2009). Therefore, the precipitation data before the outbreak of debris flows was collected from local meteorological bureaus, and used as one of the main influence factors to assess the susceptibility of debris flows in this study. In this work, the antecedent precipitation is classified into three categories: inadequacy, medium and adequacy. The classification criteria are listed in Table 1.*" (Page 5, Lines 127-131)

Table 1 Qualitative grading criteria of antecedent precipitation

Classification	***Standard of classification***
Inadequacy	*There is no antecedent precipitation or very little antecedent precipitation, which is not enough to make the surface soil moist.*
Medium	*The antecedent precipitation is intermittent or less, the soil is wet or muddy.*
Adequacy	*The precipitation lasts for several days, and the soil layer is full of water. Water accumulated in some low-lying areas, and the drainage is not smooth.*

4. The results of the field tests mentioned in Section 3.2 should be provided and discussed.

Answer: Thank you for this suggestion. The results are provided and discussed as follows:

"*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)

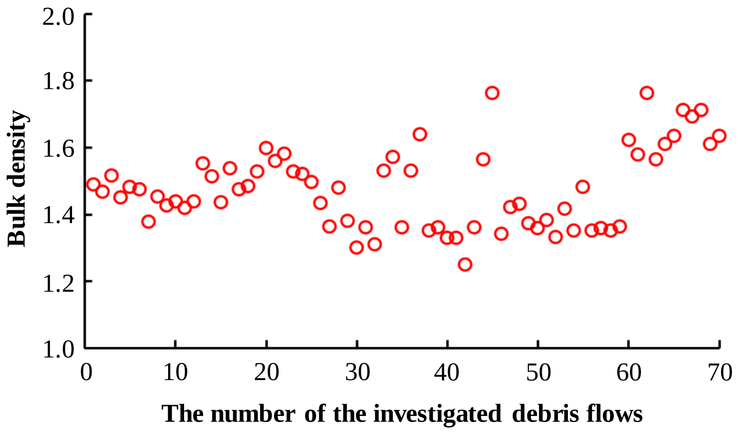

Fig.3 Density characteristics of the debris flow deposit in the study area.

5. In the Section 5.4, 10 debris flow gullies in the Kaka basin were analyzed to verify the accuracy of the prediction model. Please analyze the reasons why the prediction result of the Linong Gully does not match the actual susceptibility.

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

"*Figure 8 shows the catchment of the Linong Gully. The total area of the catchment is about 10.09 km2, and the total amount of loose material is about 4.04×10^6 m^3. The soil material, as shown in Figure 9, is mainly composed of block and crushed stone. Their particle sizes are generally 10-40 cm. In the calculation process, the catchment area is quite large, and then the loose material per catchment area is relatively very small, as shown in Figure 8. Based on the data, the prediction susceptibility of the Linong gully is 2.421, which is very close to the high susceptibility threshold value 2.5. Therefore, although there is a minor deviation, it can still be concluded that the proposed model can perform well to predict the debris flow susceptibility in Southwest China.*" (Pages 10-11, Lines 241-247)

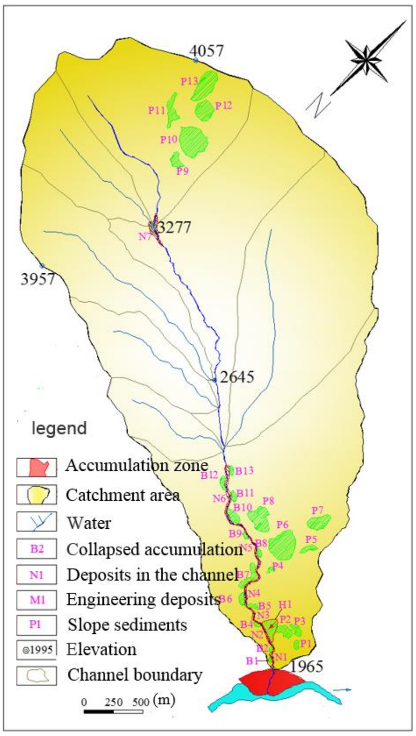

Fig. 8 Distribution of loose deposits of Linong gully

Fig. 9 Soil material in the Linong Gully deposit

6. The quality of Figure 2 and 3 should be improved. For example, the horizontal axis is not correct.

Answer: We have revised these figures according to this comment.

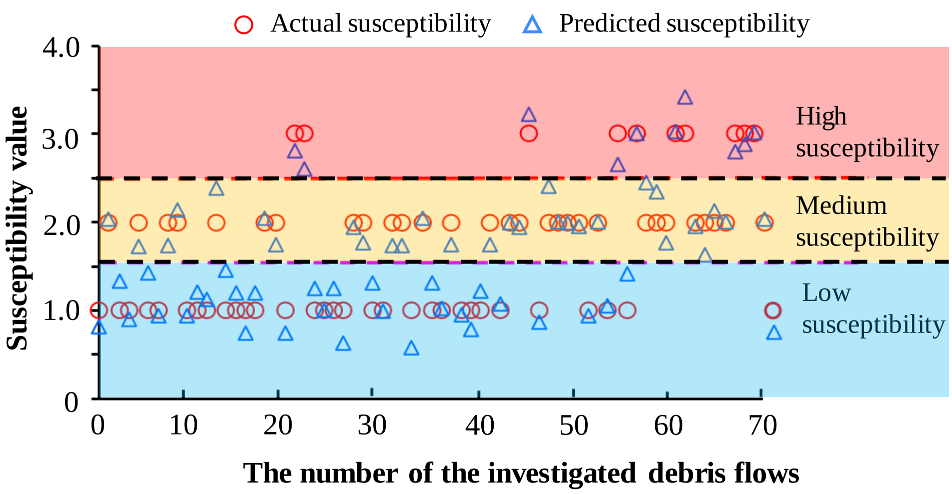

Fig.4 Comparison of actual susceptibility and predicted actual susceptibility.

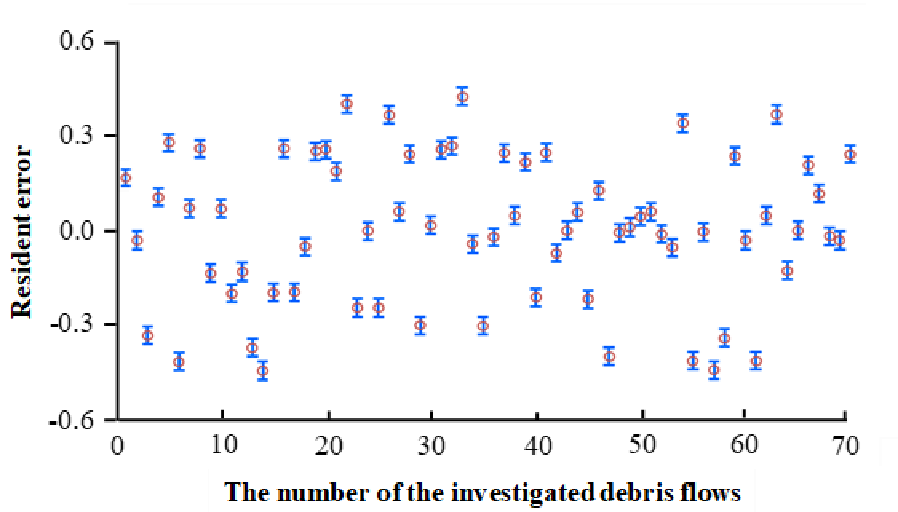

Fig.5 Residual distribution in the regression model of debris flow susceptibility.