Reviewer #1's Comments

1. General comments

The paper entitled "Regional-scale GIS-models with fuzzy logic for Susceptibility Maps of debris flow: A Case Study in Pinggu District of Beijing, China", focused on the debris flow susceptibility map computation of a series of drainage basins of the Pinggu District of Beijing. The authors proposed a methodology based on GIS-models, combining diverse methods: grey relational method, data-driven and fuzzy logic methods. The manuscript deals with the application of susceptibility analysis on debris flow. The topic is interesting and is suitable for the journal. The model used in the manuscript not only considers the scientificity and accuracy, but also considers the application in engineering practice. I think the article can be acceptable after some revisions are made.

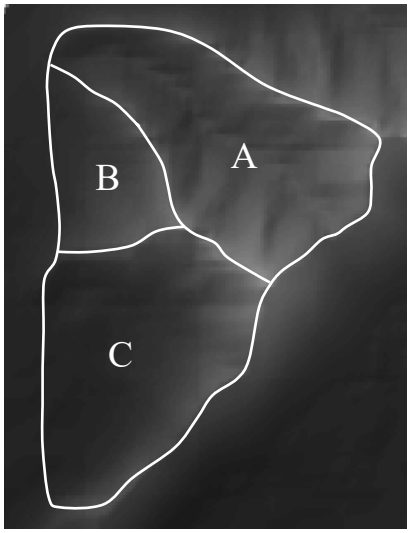
Response: Thank you very much for your valuable and constructive comments on this manuscript. Your comments are very helpful for us to improve the manuscript. Based on your comments, we have carefully revised the relevant content of the manuscript. Please see the specific responses below for more details.

2. Specific comments

***Comment 1*:** In ArcGIS, the watershed algorithm is to obtain the sub watershed units of the whole Pinggu region. How can the author select these specific watersheds in the article? How are other unqualified units excluded?

Response: Thank you for your professional comments. According to your suggestions, we screened the watersheds, which is one of the features. We first removed the flat areas from the study area and then divided the remaining watersheds using the hydrology module of ArcGIS. The specific process is divided into the following steps: (1) Filling the initial digital elevation model to eliminate the common errors caused by the resolution and rounding of the data. (2) Encoding the outflow direction of each pixel in the grid based on an 8-direction algorithm. (3) Calculating accumulated flow as the accumulated weight of all cells flowing into each downslope cell in the output raster. (4) Applying a threshold to the results obtained by the flow accumulation tool based on a condition function and describing the drainage network of the study area. (5) Extracting the basic drainage basins unit of the study area, that is, the basic unit for susceptibility assessment. The fourth of five steps, threshold determination is a factor of subjective human choice, and my current research involves how to choose this parameter objectively.

In our research, typical valley debris flows are the major research object. Therefore, as shown in the figure below, A has typical watershed characteristics, but B and C do not. There is another advantage of determining the length of the main ditch in the watershed parameter characteristics. For watersheds without obvious watershed characteristics, it is difficult to determine their length from the picture. Similarly, the calculation of drainage density is very difficult.



***Comment 2*:** How to explain the similarities and differences between models R6-R17?

Response: Thank you for your professional comments. Table 5 is one of our most important findings. It is our illustration of the results in terms of the emphasis on non-linear combinations of factors rather than simple linear superposition. In order to characterize the development of debris flows in an area, information mining is an effective means. The similarity of the models is that the individual R6-R17 models are all calculated using fuzzy logistic operations and perform well in the AUC test. The differences are that the data are pre-processed differently when using this algorithm. However, four of the models performed above 94, mainly due to the small number of watersheds in the study area and the small number of mudslides that could be used for the test.

***Comment 3*:** The introduction needs a section concerning susceptibility methods.

Response: Thank you for your professional comments. According to your suggestions, we have read more literature to add to the relevant research developments.

Communicating information about debris flow hazard analysis is a crucial component of preparedness and hazard mitigation (Chiou et al. 2015). Susceptibility assessment, an important part of a hazard assessment of geological processes is more flexible (Li et al. 2021a). In the early days, the susceptibility assessment of debris flows was mainly qualitative research using geomorphological information (Guzzetti et al. 1999). In 1976, the United Nations commissioned the International Union of Engineering Geology to conduct a risk assessment of debris flows, which marked the beginning of research on the susceptibility assessment of debris flows as an important research direction for disaster prevention and prediction (Li et al. 2020b). Many methods and techniques have been proposed to evaluate debris flow susceptibility assessment based on different qualitative and quantitative approaches and geo-environmental information (Liu and Wang 1995), Such as the analytic hierarchy process (Wu et al. 2016), logistic regression method (Conoscenti et al. 2015, Regmi et al. 2013), information value (Akbar and Ha 2011, Melo et al. 2012), support vector machine(Pourghasemi et al. 2017), frequency ratio (FR) (Sun et al. 2018), certainty factor (CF) (Tsangaratos and Ilia 2015), neural network (Lee et al. 2003, Liu et al. 2005) and Bayesian network algorithm (Liang et al. 2012, Tien Bui et al. 2012), etc. These methods have corresponding advantages and limitations for

research subjects with different geological conditions. Generally speaking, it is easier to get satisfactory results by combining and comparing various methods (Di Napoli et al. 2020, Fang et al. 2020, Meyer et al. 2014). In summary, with the development of mathematical theory, the susceptibility assessment of debris flows has been extensively and quantitatively studied, and the research methods have also changed from single to comprehensive.

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***Comment 4*:** The Results and Discussion needs to be more detailed and organized.

Response: Thank you for your professional comments. According to your suggestions, we will carefully and exhaustively sort out the ideas in the article. Then the discussion and conclusion will be reorganized to make this section more logical and systematic as well as readable.

Through the original modelling process, relatively satisfactory results are obtained in this paper. The predictive performance of the output debris flow susceptibility maps, obtained from seventeen different models, is verified by comparing with maps published by authority. By comparing the results, the following results are discussed:

First, comparing R_1, R_2, R_3, R_4 and R_5, it can be concluded that the model based on field investigation and expert experience is more effective than data- driven directly, when the sufficient information cannot be obtained. This is mainly because when the basin area reaches a certain size, it is no longer controlled by one or several factors, but becomes a complex system. It is not only the factors that affect the system, but also the system will react on each factor. Geomorphic evolution is basically the result of the interaction of the endogenic and exogenic geological processes. A geological period can be regarded as the beginning of an endogenic geological processes to the next one. In the early stage of geological period, endogenic geological processes play a major role, and in the later relatively stable period, exogenic geological processes will play a more and more important role. In this large cycle, the basin continuously occurs a small cycle of accumulating and releasing energy, which leads to extremely complex system changes. In addition, there is a contradiction between the scale of geological evolution and the scale of engineering activities. So limited information can be obtained under these conditions that leads to the unreliability of data-driven evaluation. Therefore, in the current period, field investigation and expert experience are fundamental.

Second, by comparing R_4 and R_5, R_6 and R_9, R_7 and R_{10}, R_8 and R_{11}, R_{12} and R_{15}, R_{13} and R_{16}, R_{14} and R_{17}, it can be concluded that the accuracy and resolution of the model can be improved by simplifying the factors, which will eliminate the weak correlation and independence factors. In practical application, even if the susceptibility map is obtained, the classification of the susceptibility degree is still a very difficult problem. Because everyone's subjective definition of

"susceptibility degree" is different. By simplifying the factors, the main factors can be selected, which magnifies the differences between basins, so the boundaries between different susceptibility degrees are more obvious.

Third, by comparing R_6 and R_{12}, R_7 and R_{13}, R_8 and R_{14}, R_9 and R_{15}, R_{10} and R_{16}, R_{11} and R_{17}, it can be concluded that the model in which factors are classified into two types is better than the method in which all factors as a single thematic layer without classification. Because the factors categorized separately are more closely linked and has consistent influence on the system in mechanism. We can also infer that the non-linear combination characteristics between different types are stronger and scientific classification can improve the performance of the model.

Fourth, comparing R_{12} and R_{13}, R_{15} and R_{16}, it can be concluded that the frequency ratio method is better than the cosine amplitude method in the study. Different from the study of Kritikos et al. (2015), the watershed unit rather than the grid unit is used, which indicates that the former has a wide range of application, while the latter has a disadvantage of strict conditions.

Based on the results of the above four analyses, the most optimal model should have the features of being based on expert experience, using selected factors, classifying factors before using them, and using frequency ratio method. Then the model R_{16} is selected according to the features, which is well in accordance with theoretical method performance score, and gets fine mutual verification.

There is much to discuss, the selection of factors is still a very complex dilemma. Although 19 factors selected cannot fully evaluate the character of a basin, it is necessary to consider that they are easily and relatively accurately obtainable for each basin. This will facilitate a wide range of applications. Vegetation and rainfall factors are also very important, but there is little difference in vegetation and rainfall across the study area. As for the factors describing debris flow magnitude, usually, several channels have the recorded data. Other factors that also influence the susceptibility of debris flow are usually difficult to obtain, including soil drainage, induration, thickness, conductivity, and strength properties; subsurface flow orientation; bedrock fracture flow; and root strength. The scientific and systematic principles of model building is another challenge. In order to correctly classify the factors, it is necessary to grasp the characteristics of the formation, movement and accumulation of debris flow. Therefore, the classification should comprehensively consider the development background (geology, geomorphology, climate, hydrology, soil, vegetation, human activities and other factors). The practical principle refers to that the study should not only fully obtain scientific and accurate results, but also make the professional results understood by decision makers. The relative simplicity of the model with data easy to obtain is attractive, which can also provide necessary information for debris flow mitigation and land utilization. Although the susceptibility grade and susceptibility value of each watershed is obtained, the results are relatively effective in this study area. In addition, with the development of technology and theory, we should replace some traditional factors which are not easy to quantify with more precise quantitative factors to improve the efficiency and accuracy of evaluation, such as surface roughness instead of drainage density.

***Comment 5*:** Line 26 by the results → by results

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 6*:** Line 26 validated by the other two → validated by two other

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 7*:** Line 27 the method to → a method to

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 8*:** Line 47 significance to establishing → significance to establish

Response: Thank you for your professional comments. According to your suggestion, we will correct the expression.

***Comment 9*:** Line 76 disaster chain and that the geomorphic → disaster chain and the geomorphic

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 10*:** Line 76 rather than simple data fitting → rather than simply data fitting

Response: Thank you for your professional comments. According to your suggestion, we will correct the expression.

***Comment 11*:** Line 80 account for → accounts for

Response: Thank you for your professional comments. According to your suggestion, we will correct the expression.

***Comment 12*:** Line 90 1. Data and Methodology → 3 Data and Methodology

Response: Thank you for your professional comments. According to your suggestion, we will correct the number.

***Comment 13*:** Line 99 watershed characteristics factors → watershed characteristic factors

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistakes.

***Comment 14*:** Line 103 our primary assumption here are → our primary assumptions here are

Response: Thank you for your professional comments. According to your suggestion, we will correct the expression.

***Comment 15*:** Line 103 First → Firstly

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 16*:** Line 105 Second → Secondly

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 17*:** Line 114 by professional team → by professional teams

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 18*:** Line 138 factors (Type B) factors → factors (Type B)

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake..

***Comment 19*:** Line 159 a effective method → an effective method

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 20*:** Line 169 3.4 fuzzy memberships → 3.4 Fuzzy memberships

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 21*:** Line 217 can be used to derived their fuzzy → can be used to derive their fuzzy

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 22*:** Line 238 order to use properly → order to use it properly

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 23*:** Line 247 Compared with other four fuzzy operator → Compared with other four fuzzy operators

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 24*:** Line 247 Fuzzy Gamma (Eq.6) → Eq.5

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 25*:** Line 261 seventeen results were compared (Table.6) → Table.5

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 26*:** Line 278 the results is not comprehensive → the results are not as comprehensive

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 27*:** Line 282 there are total 135 basin → there are total 135 basins

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 28*:** Line 306 uncertain factor compared with factors compared → uncertain factors compared

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 29*:** Line 309 bedrock fracture flow; and root strength → bedrock fracture flow, and root strength

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 30*:** Line 334 in which all factors as a single → in which all factors are considered as a single

Response: Thank you for your professional comments. According to your suggestion, we will replace the expression.

***Comment 31*:** Line 362 nonlinear methods is consistent → nonlinear method is consistent

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

***Comment 32*:** Line 377 clear and the data easy to obtain → clear and the data is easy to obtain

Response: Thank you for your professional comments. According to your suggestion, we will correct the mistake.

We thank you very much for not lowering your evaluation because of our poor English. The recognition of the value of our research is a great encouragement to us. We have tried our best to improve the manuscript and made changes in the manuscript. We appreciate for your warm work earnestly, and hope that the result will meet with approval. As the manuscript has undergone several previous revisions, there are many errors in detail. We apologize for the very bad effect on your reading experience. Once again, thank you very much for your comments and suggestions! Please feel free to contact me, if any further changes are required. We look forward to hearing from you.

Yours sincerely,

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