

Response to reviewer comments

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Scale and spatial distribution assessment of rainfall-induced landslides along mountain roads

revised for publication in

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by

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First of all, we wish to thank the first reviewer for the valuable comments to the manuscript and constructive suggestions that significantly improved the manuscript. In this revised version of the paper, we have tried our best to address the comments and incorporate as much of reviewers' recommendations. Our detailed reply to general comments, specific comments and technical corrections are reported below. Except this response, we prepared two manuscript files, one with "track changes", another is clean version.

General comments

C1: The paper proposes an analysis of landslide susceptibility in a mountain area, crossed by a road and affected by landslides triggered by typhoons. The topic could be interesting to NHESS readers, if some issues are more clearly presented, in particular, the aims, the used methods (in a right temporal sequence), and expected results.

R1: We have confirmed the reviewer's comments and the aims, the used methods and results have been reorganized in the revised manuscript. Detailed responses are listed in specific comments and technical corrections, respectively.

Specific comments

C2: Please define clearly what is the aim of scale assessment.

R2: The scale of landslide in our study is defined as landslide area. The scale assessment aims to understand the relationship between the natural environment and the spatial distribution of the landslide areas. Related descriptions are also supplemented in the fourth paragraphs of introduction, as shown in P.3, Ln.14-17 of the revised manuscript.

C3: The terminology should be checked and made uniform, with reference to the following terms: causal factors, predisposing factors, impact factors, landslide-inducing factors.

R3: Done, the term "predisposing factors" was used throughout in the revised manuscript for consistency (P.5, Ln.25, Ln.27; P.7, Ln.7, Ln.10, Ln.17, Ln.22, Ln.23, Ln.24; P.8, Ln.1; P.10, Ln.10, Ln.11, Ln.12; P.12, Ln.9, Ln.16; P.14, Ln.13, Ln.14, Ln.15, Ln.16; P.17, Ln.8, Ln.16).

C4: Reference description is not well presented, sometimes redundant, sometimes limited. Too repetition of "studies, many studies, previous studies, several studies, early research". I suggest to discuss methods and procedures available in literature, avoiding to refer to single reference with expression as, for example, X et al. used [...], Y et al. described [...], Z et al. utilized [...]. The introduction and especially the literature discussion (pages 2 and 3) about the landslide susceptibility assessment methods must be reorganized and rewritten using a clearly and well-ordered structure.

R4: Done, the literature review in the Introduction has been entirely reorganized and rewritten, we follow reviewer's suggestions to use a clearly and well-ordered structure to demonstrate related references, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C5: Aims, procedures and expected results are not clearly defined either in introduction either in methodological section. It is not clear if the study is only the highway or the whole catchment crossed by road; the study area seems to be the road according to title, but the final susceptibility map, in figure 4, is referred to the whole area. So the presence of the road is negligible at the aim of the analysis. The title does not reflect clearly the contents of the paper.

R5: We have changed the title of this paper to “Scale and spatial distribution assessment of rainfall-induced landslides in a catchment with mountain roads” to reflect the contents of the paper.

C6: Please, rephrase the paragraph 3, adding more information and details about the study area.

R6: Done, we added more information like climate and rainfall conditions of study area in the revised manuscript (P.9, Ln.6-8).

C7: About methodology, does maximum likelihood method have any disadvantages? Was the error associated with this automatic image interpretation technique calculated?

R7: The maximum likelihood method may be unsatisfactory for data with a non-normal distribution (Otukey and Blaschke, 2010), and could possible cause part error of automatic image interpretation.

Otukey, J. R. and Blaschke, T.: Land cover change assessment using decision trees, support vector machines and maximum likelihood classification algorithms, *International Journal of Applied Earth Observation and Geoinformation*, 12(1), S27-S31, doi: 10.1016/j.jag.2009.11.002, 2010.

C8: Please rewrite the paragraph 2.2 in order to describe more clearly the MHEM method.

R8: Done, we supplemented more descriptions of the MHEM method in paragraph 2.2, as shown in P.7, Ln.7-8, Ln.17-18 of the revised manuscript.

C9: I suggest to reconsider the title, because the analysis was not performed only along the road but in the surrounding territory and the image interpretation does not emerge from the title. It is not completely coherent with the contents of the paper.

R9: Done, we have changed the title of this paper.

C10: Please, reorganize the paper, by separating the description of methodology from the discussion of results. There are too much paragraphs that make confusing and difficult the readability and understanding of performed analyses, in particular from paragraph 5.2 onwards.

R10: Done, we moved the calculation formula of instability index and probability from section 5.2 to the methodology section 2.4, as shown in P.8, Ln.14-23 of the revised manuscript. And the methods were rearranged in a right temporal sequence (2.1 Maximum likelihood; 2.2 Accuracy assessment; 2.3 Rainfall analysis method; 2.4 MHEM). For the results, we moved original section 6.2 “Investigation of rainfall factors and instability index” to section 5.3 for better readability.

Technical corrections

C11: Page 1 line 8: please, move “Typhoons” at the end of the sentence.

R11: Done, we have moved “Typhoons” to the end of the sentence (P.1, Ln.9).

C12: Page 1 line 10: “topographic changes” or “surface changes” instead of “changes in slope surface”.

R12: Done, “changes in slope surface” was replaced by “surface changes”, as shown in P.1, Ln.10 of the revised manuscript.

C13: Page 1 line 10: “A multivariate statistical method” instead of “The multivariate hazard evaluation method”.

R13: Done, the sentence has been modified in the revised manuscript (P.1, Ln.10).

C14: Page 1 lines 11-12: Please, rephrase the sentence. The evaluation of landslide locations and relationship between landslide and predisposing factors is preparatory for assessing and mapping landslide susceptibility.

R14: Done, the sentence was rephrased in the revised manuscript (P.1, Ln.11-12).

C15: Page 1 line 26: please, replace “occurrence distribution” with “distribution of existing landslides” and “a set of predisposing factors such as geo-environmental thematic variables” with “a set of geo-environmental predisposing factors”.

R15: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C16: Page 1 line 27: “sediment disaster” is not an appropriate expression; please, replace it with landslides.

R16: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C17: Page 2 lines 1-3: Please modify the terminology used in this sentence. “predisposing factors” instead of “potential causes” and “triggering factors” instead of “impetuses”.

R17: Done, we changed the term usage in the revised manuscript (P.5, Ln.25, Ln.27; P.7, Ln.7, Ln.10, Ln.17, Ln.22, Ln.23, Ln.24; P.8, Ln.1; P.10, Ln.10, Ln.11, Ln.12; P.12, Ln.9, Ln.16; P.14, Ln.13, Ln.14, Ln.15, Ln.16; P.17, Ln.8, Ln.16).

C18: Page 2 lines 7-8: This sentence is a repetition.

R18: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C19: Page 2 lines 9-10: please add references about model uncertainty evaluation, for example: Wang X, Frattini P, Crosta GB, Zhang L, Agliardi F, Lari S, Yang Z. 2014. Uncertainty assessment in quantitative rockfall risk assessment. Landslides. 11:711–722.

R19: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C20: Page 2 line 10: explain what is the meaning of scale in this study: size, intensity of landslide?

R20: The scale of landslide in our study is defined as landslide area.

C21: Page 2 line 11: This sentence is a repetition.

R21: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C22: Page 2 lines 12-13: The meaning of this sentence is unclear.

R22: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C23: Page 2 lines 14-16: This sentence is a repetition.

R23: The literature review in the introduction has been entirely reorganized and rewritten, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C24: Page 2: I suggest to add some reference about AHP method (1), multivariate statistical methods (2) and landslide susceptibility assessment along roads (3): (1) Kayastha P., Dhital M.R., De Smedt F. 2013. Application of the analytical hierarchy process (AHP) for landslide susceptibility mapping: A case study from the Tinau watershed, west Nepal. Computers Geosciences, 52: 398-408 (1) Zhang G., Cai Y., Zheng Z., Zhen J., Liu Y., Huang K. 2016. Integration of the Statistical Index Method and the Analytic

Hierarchy Process technique for the assessment of landslide susceptibility in Huizhou, China. CATENA, 142: 233-244. (2) Carrara A, Crosta G, Frattini P. 2008. Comparing models of debris-flow susceptibility in the alpine environment. Geomorphology. 94:353–378. (2) Pellicani R, Frattini P, Spilotro G. 2014. Landslide susceptibility assessment in Apulian Southern Apennine: heuristic vs. statistical methods. Environ Earth Sci. 72:1097–1108. doi: 10.1007/s12665-013-3026-3 (3) Pellicani R, Spilotro G, Van Westen CJ. 2016. Rockfall trajectory modelling combined with heuristic analysis for assessing the rockfall hazard along the Maratea SS18 coastal road (Basilicata, southern Italy). Landslides. 13:985–1003. (3) Pantelidis L. 2011. A critical review of highway slope instability risk assessment systems. Bull Eng Geol Environ. 70:395–400. (3) Devkota KC, Regmi AD, Pourghasemi HR, Yoshida K, Pradhan B. 2013. Landslide susceptibility mapping using certainty factor, index of entropy and logistic regression models in GIS and their comparison at Mugling–Narayanghat road section in Nepal Himalaya. Nat Hazards. 65:135–165. doi: 10.1007/s11069-012-0347-6 (3) Pellicani R., Argentiero I., Spilotro G. (2017) GIS-based predictive models for regional-scale landslide susceptibility assessment and risk mapping along road corridors. Geomatics, Natural Hazards and Risk, 1-22. DOI: 10.1080/19475705.2017.1292411.

R24: Done, the literature review in the introduction has been entirely rewritten and incorporated all the references suggested by reviewer, as shown in P.1, Ln.25 - P.2, Ln.30 of the revised manuscript.

C25: Page 3 line 34: It is not clear how and from where the location of landslides was extracted? Are existing or potential landslides?

R25: The location of landslides was extracted from existing landslides of satellite images and verified by some field surveys.

C26: Page 5 line 13: please replace “risk” with “susceptibility”.

R26: Done, we replaced “risk” with “susceptibility”, as shown in P.7, Ln.6 of the revised manuscript.

C27: Page 5 lines 14-15: Please avoid repetitions: variability, variance.

R27: Done, we simplified the description in the revised manuscript (P.7, Ln.6-7).

C28: Page 5 lines 18-19: Please rewrite this sentence using a correct terminology, “cell” or “pixel” instead of “grid” and “class” instead of “grade”.

R28: Done, the terminology has been replaced by reviewer’s suggestions in the revised manuscript (P.7, Ln.13, Ln.14, Ln.16, Ln.23, Ln.24, Ln.25, Ln.27; P.8, Ln.4; P.10, Ln.19-20, Ln.23, Ln.24, Ln.28; P.11, Ln.6, Ln.8, Ln.12, Ln.14, Ln.18, Ln.21, Ln.24, Ln.30, Ln.31; P.12, Ln.5, Ln.6, Ln.23, Ln.24-Ln.25, Ln.26, Ln.29, Ln.30; P.13, Ln.27, Ln.28, Ln.30; P.14, Ln.15-16, Ln.18, Ln.19, Ln.20, Ln.21, Ln.22-23, Ln.24, Ln.25-26, Ln.27; P.15, Ln.1, Ln.9, Ln.12, Ln.13-14, Ln.16, Ln.17, Ln.21, Ln.22, Ln.28, Ln.29).

C29: Page 5 lines 22-23: Please rewrite this sentence, a confusing terminology has been used (causal factor, impact factor, grades).

R29: Done, the term “predisposing factors” was used throughout in the revised manuscript for the consistency and the term “grades” was replaced by “classes”.

C30: Page 6: Which is the difference between factor weight and graded score? It is not clear.

R30: For clarity, we replaced the “graded score” to “the normalized score value of classes for each factor”, as shown in P.7, Ln.17-18 of the revised manuscript. The “factor weight” represents the weight of each factor which is determined by the rank of its variance.

C31: Page 8 line 13: why 0.9?

R31: We added a citation (Chen et al., 2005) for the adoption of $k=0.9$, P.6, Ln.17 in the revised manuscript.

C32: Page 8 line 17: Is EAR expressed in mm?

R32: Yes, the unit of EAR is mm.

C33: Page 8 line 21: Is I_R expressed in mm/h?

R33: Yes, the unit of I_R is mm/h.

C34: Page 8 line 26: What is the meaning of rolling hours?

R34: In our study, the average rainfall intensity I_R is calculated in a continuous three hours interval then the calculated time interval moving one hour ahead. For example, the first I_{3R} is the average rainfall intensity for 1-3 hours, then the second I_{3R} is calculated in 2-4 hours, etc.

C35: Page 10 line 6: "thematic map of predisposing factors" instead of "map of the natural environment".

R35: Done, this sentence has been modified in the revised manuscript (P.10, Ln.8).

C36: Page 10 line 9: please make uniform the terminology, as for example causal factors, predisposing factors, impact factors, landslide-inducing factors, etc.

R36: Done, in the revised manuscript, the term "predisposing factors" was used throughout for consistency.

C37: Page 10 lines 21-22-26: please, modify "grid" and "grades".

R37: Done, the terminology has been revised throughout in the revised manuscript.

C38: Page 10 line 27: explicit the values of the six categories.

R38: Based on windward and leeward, the aspects were classified into six categories as following table:

South	157.5° ~ 202.5°
Southeast	112.5° ~ 157.5°
Southwest	202.5° ~ 247.5°
East	67.5° ~ 112.5°
West	247.5° ~ 292.5°
Northeast	22.5° ~ 67.5°
Northwest	202.5° ~ 247.5°
North	337.5° ~ 22.5°
Flat	—

C39: Page 11 line 4: what is the meaning of "geological strength"? The geological map should be classified into classes corresponding to different formations or lithological units.

R39: Done, it has been modified in the revised manuscript (P.11, Ln.5).

C40: Page 11 line 9: define the analysis function.

R40: Done, more clear information of the analysis function has been added in the revised manuscript (P.11, Ln.10, Ln.17).

C41: Page 11 lines 10 and 16: explicit the six classes.

R41: The terrain roughness and slope roughness were classified into six categories as shown in the following table:

Class no.	Terrain roughness	Class no.	Slope roughness
6	367.01-523.80	6	0.75-11.08
5	523.81-673.50	5	11.09-20.37
4	673.51-849.80	4	20.38-28.17
3	849.81-1035.00	3	28.18-34.47
2	1035.01-1231.30	2	34.48-40.66
1	1231.31-1472.40	1	40.67-55.76

C42: Page 11 lines 18 and 20: give more information about two factors.

R42: Done, more information was supplemented in the revised manuscript (P.11, Ln.20-21, Ln.23-24).

C43: Page 11 line 21: Land disturbance looks like a reclassified land use map. The highest score of disturbance is assigned to bare land, why not to roads and buildings? This is a qualitative attribution, it should be written somewhere.

R43: Based on the tendency to promote landslides, the index of land disturbance was developed (Chen, et al., 2009). The land disturbance in this paper can represent the changes of surface conditions including roads, buildings, crops, bare land, and vegetation. In these factors, we consider bare land has the highest tendency to promote landslide. We supplemented descriptions in the revised manuscript (P.11, Ln.26-27).