

Reply to Referee #2 M. Mergili (Referee)

The authors analyse the susceptibility of a study area in Portugal to shallow landslides, comparing a statistical model and a physically-based model. Thereby they split their landslide inventory into two temporal subsets, one for building the statistical model and for calibrating the key parameters of the physically-based model, and a second one for model validation. They further compare the outcomes and combine the results in order to obtain a more informative landslide susceptibility map. The topic is highly relevant, the research is well described, and the manuscript is well structured and illustrated. As it is usual for discussion papers, there is some potential for improvement. I have identified a number of minor issues which should be addressed before I can finally recommend the manuscript for publication in NHSS. All in all, I suggest minor revisions

Authors reply: We acknowledge and appreciate the positive evaluation of the manuscript made by the Referee #2.

General comments:

Reviewer comment - I suggest to refer to “statistical” instead of “empirically-based” models.

Authors reply: To this respect, we acknowledge that Reviewer #2 makes the same suggestion as Reviewer #1. We agree with the suggestion. Therefore, the title of the new version of the manuscript will be the following: “Combination of statistical and physically-based methods to assess shallow slides susceptibility at the basin scale”. In addition, any reference to “empirically-based” will be replaced by “statistical” along the text.

Reviewer comment - The illustrations are fine, but you might consider underlaying all the maps with a hillshade.

Authors reply: As suggested by the reviewer all maps in this new version of the manuscript will be underlined with a hillshade model of the study area. The suggested changes will be made in figure 1, figures 3 to 6 and in figures 8 to 10.

Reviewer comment - Even though the discussion paper is well written in general, some final polishing of grammar and style will be necessary.

Authors reply: As addressed by the reviewer a grammar and style verification through the new version of the manuscript will be made.

Reviewer comment - A further reference that could be interesting: de Lima Neves Seefelder, C., Koide, S. & Mergili, M. (2016) Does parameterization influence the performance of slope stability model results? A case study in Rio de Janeiro, Brazil. Landslides, doi:10.1007/s10346-016-0783-6

Authors reply: We read the work suggested by the reviewer and taking into account the discussion that authors make on the geotechnical spatial parameterization associated to physically-based models we decided that it is useful to quote in the new version of the manuscript

Specific comments:

Reviewer comment - p7, l14 (and several other instances in the manuscript): I think that “hydrological model” should be replaced by “hydraulic model”.

Authors reply: Although the term hydrological model had been generally used in literature considering rainfall infiltration conditions as steady state (e.g. Park, 2013; Teixeira, 2015) we agree with the review suggestion and we will change the designation “hydrological model” by hydraulic model” along the new version of the manuscript.

References:

Park, H. J.; Lee, J. H.; Woo, I. (2013) Assessment of rainfall-induced shallow landslide susceptibility using a GIS-based probabilistic approach. Engineering Geology, 161: 1–15.

Teixeira, M.; Bateira, C.; Marques, F.; Vieira, B. (2015) Physically based shallow translational landslide susceptibility analysis in Tibo catchment, NW of Portugal. Landslides, 12: 455–468.

Reviewer comment - p8, l7: What do you mean with “social” areas – maybe “cultivated” areas?

Authors reply: “Social” areas are used in the official Portuguese digital soil map at 1: 25,000 scale to describe urbanized areas. Therefore in order to avoid misinterpretations we will change the designation of “social areas” to “urban areas”.

Reference: DGADR (1999) Cartas dos Solos de Portugal - Cartas Complementares, Escala 1:25 000, Folha 389. Elaborado por: SROA/CNROA/IEADR/IHERA/IDRHa/DGADR. <http://www.dgadr.pt/nota-explicativa>

Reviewer comment - p8, 130ff: Maybe you should mention in an additional sentence (here or in the conclusions) that, through back-calculation, the geotechnical parameters lose their direct physical meaning, but are instead a product of statistics. Even though the infinite slope stability model clearly remains physically-based, in fact parameter calibration gives it a bit of a statistical touch.

Authors reply: We acknowledge the reviewer comment, and we think the observation is correct and pertinent. Therefore we will include in the conclusion just after physically-based models drawbacks the following text: “Additionally, although the infinite slope stability model still remains physically-based, the used geotechnical parameters lose in some extent their direct physical meaning, since critical cohesion and internal friction angle combination were determined statistically assuming the highest effective ratio.”

Reviewer comment - p10,122: I would not consider a rainfall with a duration of 15 days a short duration rainfall event.

Authors reply: The interval 1 to 15 days has been used to express the rainfall conditions that typically trigger shallow landslides, which contrast with rainfall periods lasting several weeks that are associated with deep-seated landslides (e.g., Zêzere et al., 2005; Zêzere et al., 2015). We acknowledge that 15 days is in the borderline between the two groups. To avoid confusion, we will keep out the reference of number of days in the new version of the manuscript.

References:

Zêzere JL, Trigo R, Trigo I (2005) Shallow and deep landslides induced by rainfall in the Lisbon region (Portugal): assessment of relationships with the North Atlantic Oscillation. *Nat Hazards Earth Syst Sci* 5:331–344. doi:10.5194/nhess-5-331-2005

Zezere, J.L.; Vaz, T.; Pereira, S.; Oliveira, S.C.; Marques, R.; Garcia, R. (2015) - Rainfall thresholds for landslide activity in Portugal. *Environmental Earth Sciences*, 73(6): 2917-2936. <http://link.springer.com/article/10.1007%2Fs12665-014-3672-0>

Reviewer comment - p14, 110f: It could also be possible to identify uncertain areas with one single model by varying some input assumptions and parameter

combinations tested and, e.g., analyzing the standard deviation of the results. Even though I agree that it is much better to compare different model approaches, you might consider to slightly reformulate your final statement.

Authors reply: We appreciate the suggestion of the reviewer and we think that the observation is correct and pertinent. Therefore we will reformulate our final sentence as: "Although it could also be possible to identify uncertain areas with one single model by varying some input assumptions and parameter combinations, our work demonstrates that the combination of both methods allowed the identification of areas classified as uncertain regarding landslide susceptibility but with potential to be highly/very highly susceptible to shallow slides occurrence, which is not possible when using a single landslide susceptibility model."

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