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Comment on nhess-2021-230

Anonymous Referee #1

Referee comment on "Evaluating landslide response in a seismic and rainfall regime: a case study from the SE Carpathians, Romania" by Vipin Kumar et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-230-RC1, 2021

The manuscript entitled "Evaluating landslide response in seismic and rainfall regime: A case study from the SE Carpathians, Romania » presents numerical simulations of the potential response of a massive landslide in Romania to rainfall and earthquake loadings. Based on geophysical measurements, the authors reconstruct the 3D geometry of the landslide using LeapfrogGeo software. Data from previous studies as well as empirical equations are used to derive landslide mass and bedrock properties. UDEC software is used to assess the factor of safety of several 2D cross sections within the landslide mass along with their displacements considering various settings - dry or wet, static or dynamic – to account for expected rainfall and earthquakes regimes in the area. RAMMS software is then used to assess travel lengths, debris heights and velocities and affected areas of potential debris flow considering different initial volumes of erodible materials.

These topics are worthy of investigation within the scope of NHESS. Yet, in the opinion of this reviewer, the manuscript needs to be clarified prior to any publication considering in particular the important points mentioned below.

- Description of the study area

Description of the rainfall context of the area

The description of the rainfall-related data is not sufficiently complete : more details should be provided in the text regarding how (instruments) and where (location with respect to the landslide site) rainfall, surface runoff and soil moisture were acquired.

Data shown in Fig. 3 and Fig. 4 do not allow to draw conclusion of a clear increase in the trend of annual rainfall (and other related parameters) in the area that could favor landslide reactivations in the future. The increase mentionned in the text (line 120, Fig. 3 and Fig. 4) strongly depends on data binning : if one selects years 2001-2010 as the first bin for example and years 2011-2020 as the second one, the conclusions could be the opposite. More data analysis is therefore required : in particular, standard deviation values need to be added to the average values depicted in Fig. 4. Are the relative differences in annual rainfall (and other related parameters) averages (including their standard deviations) really meaningful between the two periods of times ?

Is the time scale of a year (line 122) appropriate to draw the conclusion of a link between rainfall and debris flows / flash floods given that « water related parameters » strongly vary over the year ? How many debris flows and flash floods were registered during these two periods ? Is it significantly larger than those observed over the other periods ? How comes that the relatively high amounts of rainfall in years 2013 and 2016 did not lead to increased surface runoff and soil moisture ? The authors should provide additionnal information to support their conclusions.

Description of the seismic context of the area (line 146, fig5)

Why don't the authors comment on the distribution of earthquakes with respect to the location of the case study ? How far the epicenters are from the landslide site ? Can we expect them to have an impact on the triggering / reactivation of the landslide ? Most earthquakes in the area have a magnitude smaller than 5. Besides these earthquakes are quite deep : can they trigger landslides ?

Description of the Varlaam landslide

The authors intend to study the effects of rainfall and earthquakes on landslide occurrence in the study site: are there any established correlations between landslides and earthquakes or rainfall in this area? Have they changed over time ? Further references could be added to illustrate the Varlaam landslide reactivations over time and their causes.

- Description of the methodology

The methodology needs to be outlined clearly, in more details. In particular, a better balance needs to be found between the description of the methodology and the results of both types of numerical approaches : landslide triggering modeling on the one hand with UDEC software and debris flow runout simulation on the other hand with RAMMS software. Additional data pocessing should be provided to support the interpretations and the conclusions.

Numerical modeling of the factor of safety and displacements considering various settings

- The meaning of « potential material displacement » (line 204) needs to be clarified in the text. Do those displacements refer to : 1) Displacements after the model has reached static equilibrium (under gravity only) or 2) displacements obtained at the end of the factor of safety calculation using the shear strength reduction technique ? In both cases, the displacements are not meaningful in terms of absolute values.

- Boundary conditions selected along the base of the model for the static and the dynamic runs should be better explained (line 200, Fig. 7). Why do the authors select x-viscous boundary for the dynamic simulations (and not x- and y-viscous boundaries as it is more often done) ?

- How representative are the seismic inputs (Fig. 8) of expected earthquakes in the region ?

- How was groundwater introduced into the models ? Did the authors conduct a fluid-flow calculation (either coupled or uncoupled with the mechanical stress calculation) prior to the factor of safety calculations to derive static intial stresses under wet conditions ? How was water considered during the dynamic simulations ? Did they use a static water table (no fluid flow) enhancing fluid pressure on the ovelying medium and therefore reducing its factor of safety. If so, this should be clarified in the text.

- Is « partial loss of shear strength during seismicity » (line 449) explicitely taken into account in the modeling ? If so, this should be described in details in the methodology.

Numerical simulation of debris flow runout

- The description of the RAMMS software in terms of governing equations could be enhanced. What kind of forces may act within the moving mass during the landslide propagation process ? How cohesive or non cohesive is the expected flow? How can the modeling parameters be related to soil physical properties or to saturation conditions ? A sensitivity analysis on the impact of the selected flow resistance parameters (friction and turbulent coefficient parameters) on the outputs (predicted runout zones and characteristics in terms of flow velocities and heights) could be added as other papers (see Zimmermann et al., 2020 - doi:10.3390/geosciences10020070 - for example) showed that results strongly depend on those parameters. What is the user selected stopping criteria for the debris flow simulation ? What is its impact on the modeled deposition patterns ?

- The understanding of the initial conditions (ie. quantity of expected entrainment material) leading to the debris flow occurrence is not straightforward : is it a block release that initiates the propoagation ? Do the values of « 5, 10, 15 or 20m of material depth » mean that from Fig. 7, all debris from top to the bottom of the landslide, down to a depth of 5, 10, 15 or 20m correspond to the initial release material for landslide runout simulations ? If so, could the authors further quantify each event in terms of initial volume of debris in Fig. 14 d, g, j and m ? With this assumpion of an initial erodible depth of loose materials, does this mean that the initial volume at release may not be continuous within the landslide (in particular for the 5m depth, Fig. 14 d to f) ? More details could be provided in the caption of Fig. 14b on the different depths used in the modeling.

- Description of the main results of the modeling

Additional data pocessing should be provided to support the interpretations and the conclusions.

Numerical modeling of the factor of safety and displacements considering various settings

- In this part of the modeling, some paragraphs could be shortened - for instance, the impact of the internal friction angle on the factor of safety is well known ; same for the impact of a wet material vs a dry material – wheareas others could be added - to strengthen the conclusions on ground-motion amplifications and shed light on the causes of such amplifications, purely topographic ground motion amplifications could be added along with 2D/1D aggravation factors.

- In the outputs of the modeling of the factor of safety and displacements, the authors could comment more on the landslides locations/characteristics as a function of external loadings (either by rainfall only, earthquake only or both types of events, Fig. 9). Besides, using results from all the four 2D longitudinal cross sections, the authors could provide the readers with a first approximation on the overall 3D behaviour of the landslide

Numerical simulation of debris flow runout

- Fig. 14f : could the authors comment on the very large peak of flow velocity on the left bank of the river ? Why do the colorbars include blank color between for example different shades of blue ?

- How important is the hillslope topography and valley shape on the spreading of the debris flow ?

- The authors mention that « runout findings … follow the same spatial extent as possibly followed by previous landslide events » : could they add information / plots to support their conclusions.

- Summary

The paper ends with a summary that provides an overview of the main results. It could be shortened to leave more space for a discussion (that is currently reduced to lines 633-637).

- Additional minor comments

- in the abstract, the modeling approaches used in this paper should be mentionned.

- line 36 : Froude and Petley (2018) studied « fatal non-seismic landslides ». Please select another reference to show the need for such a study.

- Fig. 3 : what is the purpose of a polar plot representation in a to illustrate time evolution of annual rainfall ? Besides, it is counter intuitive that past is in the right and present in the left. Average monthly rainfall could be added in each plot of Fig. 3b to ease the link with Fig. 4. Meaning of « Spatial resolution: 0.1° » in the caption ?

- Fig. 4f : please add the time axis to ease reading of the plot

- line 392 : « this effect is attributed to the shear strength reduction approach » : this statement is not correct. The increase of the factor of safety is a consequence of an increase in the shear strength of the soil as a consequence of the increase in the angle of internal friction of the soil.

- Fig. 12 : Because plots are hardly readable, respective values of PGA could be added on top of each subplot.

- paragraph 4.1.4 : why not showing a transfer function plot that would be more informative than several curves of spectral ratios at given locations along the slope surface ?

- Fig. 5b : this zoom plot does not provide additional information with respect to plot 5a

- Fig. 7 : the possible locations of the water table inside the model are not clear to this reviewer

- Fig. 8 : plots showing the ranges of frequencies of the selected input motions could be useful. How were selected their PGA ?

- Fig. 10d : can the authors comment on plot 10c where mean displacements in dynamic-dry conditions are larger than those in dynamic-wet conditions ? The authors could comment on the respective role of PGA and the frequency contents of the input motions on the final displacements. To support this point, showing the frequency contents of the inputs could help.

- Fig. 11 : the extreme values of the vertical axis are not appropriate in plots a to d (and in plots e to h). Plots from i to l do not allow for an easy quantification of the increase or decrase of displacements as a function of slope parameters (for instance elastic modulus) or conditions. In plot d, the elastic modulus refers to which parameter of the soil ?

- Fig. 12 : please add the horizontal axis (time) on all subplots

- Fig. 13 : which displacements are reported : surface or inside the landslide mass displacements ?

- Fig. 15 : the quality of the insets plots could be improved.

- table 1 : unit for shear stiffness could be added (in addition to kn/10)