Landslides triggered by the 2015 Mw 6.0 Sabah (Malaysia) earthquake: inventory and ESI-07 intensity assignment

Response to Reviewer 2

I wish to thank Vipin Kumar for the thoughtful comments, which helped in improve the quality of the manuscript. Here I provide a point-to-point answer to all the comments raised by reviewer 2. Original comments are shown in *italic*, while my answer is in plain text.
Following the editorial comments, I added the copyright icon in Figure 2c and I now use the color scheme of Crameri et al. (2020).

RC2: 'Comment on nhess-2022-69', Vipin Kumar, 30 Apr 2022 reply
Comments on the research article (NHESS-2022-69):

Author aims to elaborate spatial patterns of earthquake (2015 Mw 6.0 Sabah (Malaysia) triggered landslides using Landslide Number Density (LND) and Landslide Area Percentage (LAP). Author further applies the Environmental Seismic Intensity (ESI) scale-2007, considering epicentral intensity of IX (based on landslide affected area). The ESI-07 is used by utilizing the volume of landslides, which is determined using published landslide Area-Volume scaling relationships. The article is mostly well written except few clarifications/elaborations that will make potential readers having diverse backgrounds more interested.

Comments:

Author needs to include both pre-earthquake landslide (if any) and post-earthquake landslide inventory of the study area to effectively demarcate the "co-seismic landslide affected area". This affected area is crucial in view of the utilization of ESI-07 scale.

Agreed. In the original paper, I did not focus on pre-existing landslides, since from a visual overview of the satellite images they seemed negligible.
Following the reviewer suggestion, I now realize an inventory of landslides that were already existing before the earthquake occurred on 4 June 2015. While the co-seismic landslide inventory was realized on a homogeneous dataset of satellite images provided by PlanetScope, similar images are not available for the timeframe antecedent the earthquake. Thus, I used Google Earth historical images, ranging from 19 May 2008 to 2 June 2015; this process results in a dataset much more heterogeneous

with respect to the coseismic inventory. Additionally, cloud-free images are not available for 186 km^2, corresponding to 23% of the total area (namely, 810 km^2-wide).

Figure 1 shows the position of pre-existing landslides with respect to the study area. Inside the pale blue area, no cloud-free images are available. The inventory contains 225 landslides, having a total area of 0.55 km^2. For the sake of comparison, the coseismic inventory described in the paper contains 5198 landslides, having a total area of 18.84 km^2.

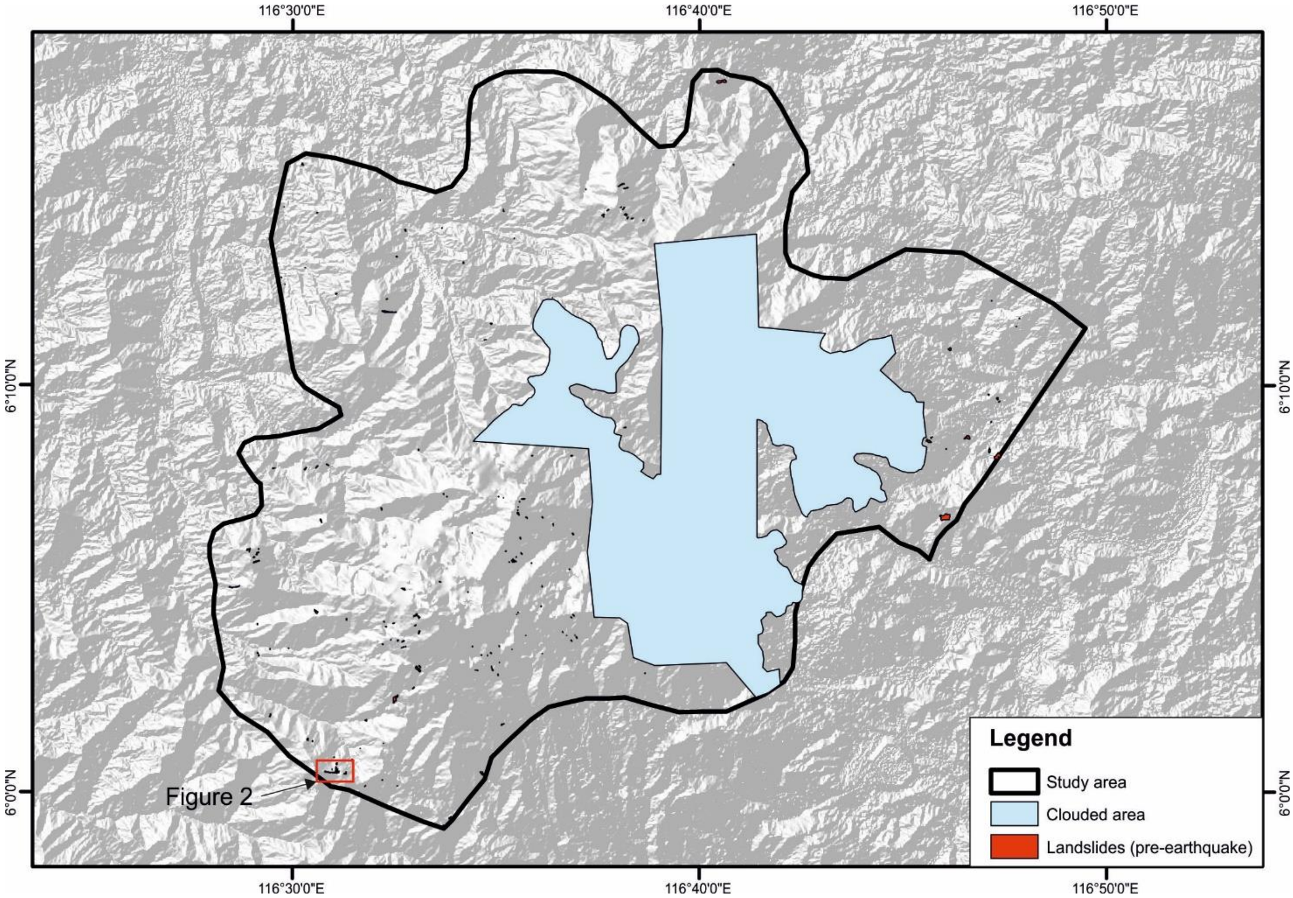

Figure 1: study area (black polygon) and inventory of landslides mapped on images acquired May 2008 and June 2015. The pale blue area represents a region where cloud-free pre-earthquake imagery is lacking.

Figure 2 shows an example of multi-temporal images, acquired between 2013 and 2018. The oldest image was acquired in July 2013 and shows a slope movement at the bottom right corner; the second image was acquired one year later (July 2014) and shows more widespread landslides.

The last image was acquired in August 2018 (i.e., after the 2015 Sabah earthquake); it can be noticed that some of the former landslides are no more clearly recognizable in the image.

Figure 2: multi-temporal images, showing the evolution of landslides through time. Location is shown in Figure 1.

Author also needs to recalculate the LND and LAP in view of the possible changes in the inventory caused by exclusion of pre-earthquake landslides.

The pre-earthquake landslide inventory, described in the previous response, is significantly smaller than the co-seismic inventory: the former includes 225 landslides, while following the earthquake I mapped 5198 landslides.
In Figure 3, I provide a map of LND and LAP referring solely on the pre-earthquake landslides and I compare them with the coseismic landslides. It is evident the very limited role of preexisting landslides, either in terms of Landslide Number Density (LND) and of Landslide Area Percentage (LAP); more than 95% of the grid cells belong to the lowest class (LND 0 – 1, Figure 3a), while more than 99% of the cells belong to the lowest LAP class (Figure 3b; max LAP value is 0.09%).

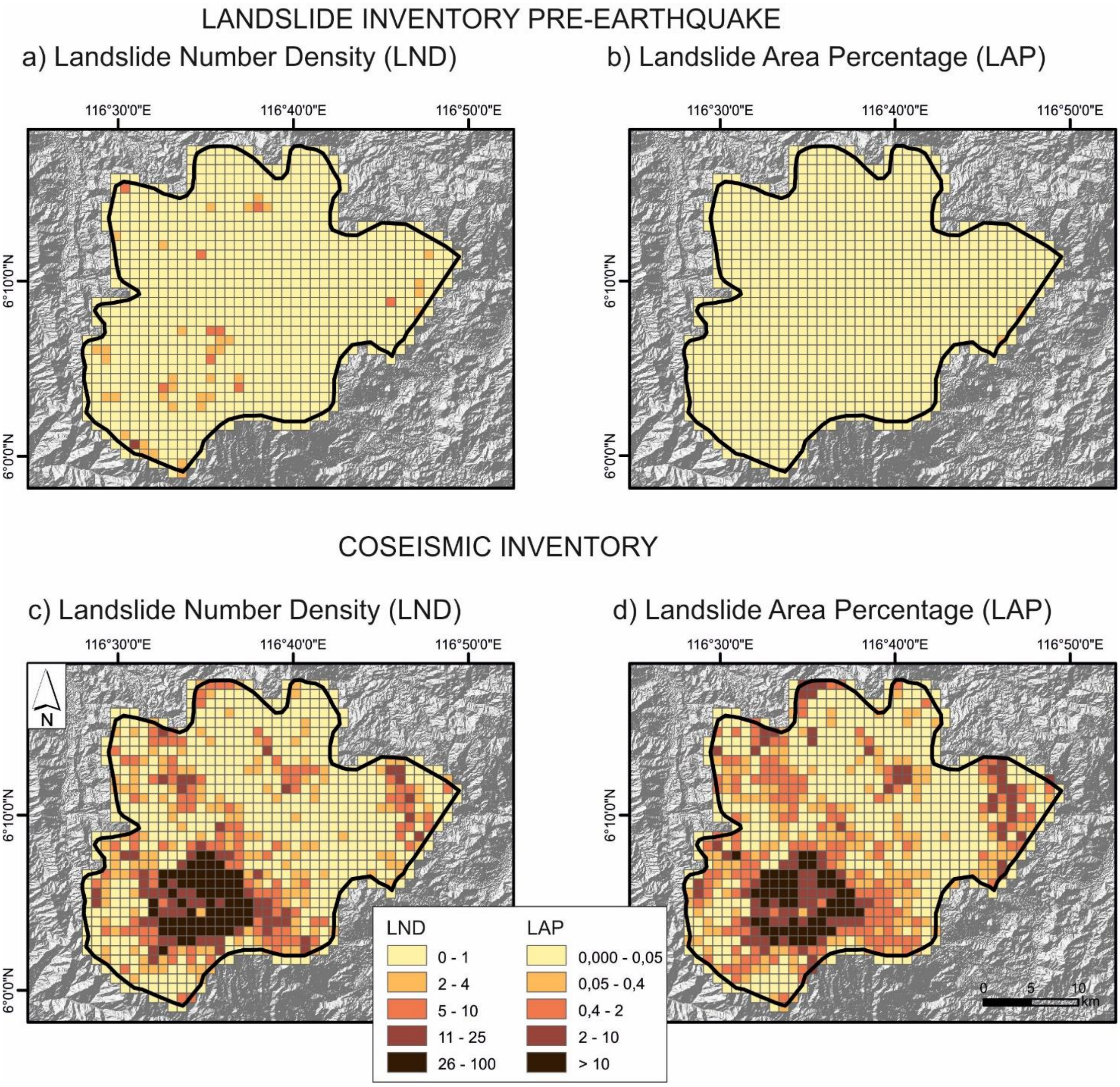

Figure 3: comparison between LND and LAP computed on the landslide inventory preceding the earthquake (a, b) and on the post-seismic inventory (c, d).

Following the above reasoning, I did not include the landslide inventory preceding the earthquake, mainly because it is less reliable from the methodological point of view (see above the response to the first comment).

In the manuscript, I added in Section 4.1 a few lines to clarify the negligible influence of pre-existing landslides on the ESI-07 intensity assignment.

Though it might be difficult to classify 5198 landslides based on type, effective usage of the landslide area-volume (A-V) scaling relationships require type classification. Most of these A-V *scaling relationships have been obtained in specific geological and/or climatic settings and have been subjected to defined hillslope material. Notably, Larsen et al. (2010), who used an inventory of >4000 landslides, observed that γ varies based on hillslope material. Further, why did the author include only 6 of the many published landslide A-V scaling relationships?*

In the Sabah inventory, I did not attempt to classify the slope movements according to their type, since my mapping is based on satellite images only. Indeed, such classification would have required detailed field data. It must be underlined that only a small part of the available earthquake-induced landslide inventories includes a genetic description or a classification of the type of movement. For the purposes of the current study, i.e., classification of the earthquake effects using the ESI-07 scale, the input data is the volume of individual slope movements.
In the revised version I consider 8 A-V relations instead of 6 (see next response); I based the selection of these relations among the many published ones on some (rather subjective) criteria, favoring those with global validity (Guzzetti et al., 2009; Larsen et al., 2010) or explicitly related to earthquake-triggered movements (e.g., Xu et al., 2016; Massey et al., 2020).

Earthquakes generally result in many rock fall type landslides, as the author also showed in Fig. 2c. Author could have included some A-V relationships that have been proposed for rock falls.

In the revised version of the paper, I consider 8 A-V relation; I added 2 relations specifically dealing with rockfalls. Benjamin et al. (2018) investigated rockfalls on coastal cliffs at Staithes (UK); they compute the volumes adopting 2D and 3D change detection algorithm from Terrestrial Laser Scanner point clouds. In the paper, I consider their 2D equation, since I believe this method is more similar to the other considered relations and can be more widely applied. Caputo et al. (2018) studied rockfalls on coastal cliffs at Coroglio (S Italy), estimating the A-V relations from Terrestrial Laser Scanner data.
One limitation of the Benjamin et al. (2018) and Caputo et al. (2018) relations is the dimension of the individual rockfalls: in the former study, the biggest rockfall is of 27 m^3, while in the second study the samples have an area of 0.1 – 10 m^2. The extrapolation of the A-V relations to much bigger landslides should be carefully considered; nevertheless, the application of the 8 relations considered in this study clearly show a similar picture in terms of ESI-07 distribution, testifying that input data (i.e., landslide inventory) is far more important than the choice of the A-V relation.