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Discussions

Interactive comment on "Temporal evolution of landslide hazard for a road infrastructure in the Municipality of Nocera Inferiore, Italy, under the effect of climate change" *by* Marco Uzielli et al.

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The Authors wish to thank the Reviewer for his/her comments. Please see below the detailed responses by comment number.

Comment 2.1 Definition of the statistical model: the authors use two variables derived by rainfall measurements as proxy of landslide triggering: 1-day rainfall and 59-day rainfall. The choice of these variables is briefly mentioned by the authors (page 6 – lines 7-9) but is totally unclear. Since the choice of the proxy variables is essential in the definition of probability of landslides triggering, this part deserves more space and more details.

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Discussion paper

Response: Thank you for the suggestion. In the revised version, we will clarify the rationale behind this choice. Several works (De Vita and Piscopo, 2002 ; Fiorillo & Wilson, 2004 ; Pagano et al., 2010 ; Napolitano et al., 2016 ; Comegna et al., 2017 ;Reder et al., 2018) stressed the prominent role of antecedent precipitations for landslide occurrence in pyroclastic covers. However, the effective length of such window is highly dependent from local conditions. In this perspective, for the same geomorphological context, De Vita and Piscopo (2002) use again 59 days. Preliminary analyses were conducted using a number of proxies in the calibration of the Bayesian approach developed in the paper. Such analyses showed that 1-day and 59-day rainfall could be confidently used. The results of preliminary analyses involving other proxies will be briefly mentioned in the revised version.

Comment 2.2 The authors define the hazard as the product between probability of landslide triggering and the reach probability (which, in my opinion, can be defined in a more appropriate way). The authors affirm that that probability of triggering is only related to the rainfall (parameters??) and is assumed constant over the space while only the reach probability depends on the morphology and is spatially variable. I think that these assumptions are very questionable and affect the entire research. Moreover even if the authors show this definition of hazard, it is not applied and assessed in the manuscript (no figure shows hazard maps). The figure 4 (flow chart of the study is not in agreement with the results presented in the manuscript).

Response: The definition of hazard as the product between triggering probability and reach probability reflects the quantitative approach based on conditional probability. If hazard can be defined as the probability that a specific spatial location can be reached as a consequence of the occurrence of a given combination of values of the control parameters (in this case, 1-day and 59-days cumulative rainfall), then it is conceptually correct to define this as the product of “the probability that an event is triggered given the occurrence of a given combination of value of the control parameters” (triggering probability) and “ the probability that a specific spatial location is reached in the course of the event's runout" (reach probability). The probability of triggering in this specific study is investigated in terms of rainfall parameters (the aforementioned 1-day and 59-days cumulative rainfall). Triggering probability is assumed constant within the study area since the database which is used to develop the Bayesian method refers to the area itself. As detailed in a similar study by Berti et al. (2012), the quantitative output of empirical methods such as the one developed in the paper implicitly accounts for the spatial variability (if any) of rainfall characteristics within the area. Additional text will be provided in the revised version to explain more explicitly the issue of spatial variability of triggering factors as related to the scale of analysis and to the specific study area. Triggering probability as defined in the study does not parameterize the component of landslide susceptibility related to terrain characteristics. This component is considered in the reach probability term. The numerical method used to model landslide runout addresses the spatial variability of the terrain-related susceptibility component through the specification of hillslope areas prone to slide (source areas) extracted by official mapped geo-morphological and hazard data. The source areas have been chosen in relation to the specific analyzed landslide type (i.e. ZOB and actual "niche/failure" for channelized debris flow; actual "niche/failure" for un-channelized debris flow). The terminal phases of the procedure will be addressed more explicitly through the completion of the case study example. This will be achieved through additional text, figures and tables.

Comment 2.3 The results of the triggering probability in the future (2071-2100) are questionable as well if it is inserted in the context of IPCC AR5 results for the Mediterranean area. IPCC AR5 forecasts a strong reduction of the rainfall for this area at seasonal and annual scale. Since the authors use as landslide triggering proxy precipitation at 59 days and 1 day, the increase of landslide triggering probability seems to be a little bit controversial. The reader has no tools to try to understand the reason of this behavior.

Response: The findings about future trends of daily and cumulative precipitations are provided by CORDEX initiative performing a multi-model ensemble on Europe at very high resolution. The main results provided by EURO-CORDEX are included in IPCC Assessment Reports in attempting to improve and localize the general results provided by Global Climate Models. Moreover, in our view, our results are not controversial. Indeed, the reductions assessed for cumulative values at seasonal scale can be linked to higher retention capability of atmosphere potentially induced by global warming; the same mechanism could induce increases in occurrence and magnitude of heavy rainfall events due to high amount of "precipitable" water in atmosphere.

Comment 2.4 The authors provide no assessment of the performance of the landslide triggering method.

Response: The method developed in the paper is a predictive method which looks into the future evolution of landslide hazard in probabilistic terms. Regarding the estimation of triggering probability, the Bayesian approach employed in the paper is inspired by the one proposed by Berti et al. (2012). This study, similarly to the former one, inherently incorporates past information about the empirical relationship between triggering factors and occurrence of events in the Bayesian formulation; more specifically, in the likelihood probability term. Thus, from a quantitative point of view, the Bayesian approach explicitly accounts for past evidence. The estimation of reach probability is based on the numerical modeling of landslide runout for events originating in potential source areas.

Comment 2.5 There are different assumptions (sometimes very important, especially on the derivation of the different probabilities which compose the hazard), which are not explained with the proper details and which are very questionable. The authors should add more details each time they introduce an assumption trying to explain the possible consequences of such assumptions.

Response: Thank you for the suggestion. In the revised version, we will clearly identify assumptions in the different sections. Moreover, we will clarify the points specifically identified by the two Reviewers.

Comment 2.6 In the section 6.1 the stop of run-out routing is related to the exceeding of a velocity parameter and it is not clear the role of this parameter in the method used by the authors. Also other concepts, as the persistence function, are not properly explained by the authors.

Response: Thank you for the suggestion. In the revised version, we will explain these aspects.

Comment 2.7: I'm no English mother tongue but some parts of the paper are very hard to read and to understand – I suggest the use of English native speaker to re-read the paper and correct it.

Response: The revised version will be carefully re-read to improve its readability. A native English speaker could support us in this task.

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