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Natural Hazards and Earth System Sciences
Discussions
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Interactive comment on "Estimation of the susceptibility of a road network to shallow landslides with the integration of the sediment connectivity" *by* Massimiliano Bordoni et al.

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The authors are grateful to the Anonymous Referee #2, whose comments and suggestions will contribute towards an improvement of the final paper. We will also consider the suggestions proposed by the Anonymous Referee #1. Point-by-point replies to the Anonymous Referee #2's comments follow.

Comment 1 Dear Editor, The paper Estimation of the susceptibility of a road network to shallow landslides with the integration of the sediment connectivity" by Bordoni et al. present an interesting study case for landslide susceptibility applied to roads in a small area of north Apennines, Italy. One of the main contribution (as the authors state in the title) is the integration of sediment connectivity in the statistical model, using different land use scenarios. From my point of view, the quality of the paper, the method used, the results and the discussion make the paper suitable for publication in NHESS journal. I suggest some highlights of this kind of studies in the introduction, discussions and conclusion parts of the paper. In my opinion, some minor issues must be solved before the publication.

Response to Comment 1 We thank the Referee for the appreciation of our work. In revising the paper, we considered all his suggestions and comments, which allowed to clarify several aspects and to improve the article overall quality.

Comment 2 (i) please provide more details in "the study area" section about the method used for land use mapping; also, you can move here some information about landslide inventory - data acquisition.

Response to Comment 2 We added several information about the method used for land use mapping. Regarding this aspect, we added this paragraph in "The study area" section of the paper: "...Land use maps of the study area have been available since 1954. Land use map of 1954 was realized by aerial photographs from Gruppo Aereo Italiano (Italian Aerial Group), with a resolution of 0.5 m. Further, the land use map of 1980 was obtained from photo interpretation at a scale of 1:50,000 from the TEM1 flight (scale 1:20.000). Land use maps of 2000, 2007, 2012 and 2015 were provided by the Lombardy Region and shared as part of the Infrastructure for Spatial Information in Lombardy (IIT) via the Geoportal (Lombardy Region Geoportal: http://www.cartografia.regione.lombardia.it/geoportale, last access: 11 December 2017). The map of 2000 was obtained from the photo interpretation of aerial images of Flight IT2000, with a resolution of 1 m. While, the land use map of 2007 was realized by using colour and infrared orthophotos from Flight IT2007, with a resolution of 0.5 m. The maps of 2012 and 2015, which corresponded to the actual situation, were realized through the photo-interpretation of aerial photos realized by Agency for Disbursement in Agriculture (AGEA). The photo-interpretation was also supported by auxiliary data of Lombardy Region databases (e.g. Regional Agricultural Information System, Forest Types maps, map of the resident population, Archive of Integrated Activities production). The overall accuracies of maps obtained for Lombardy Region using this methodology was reported in Zaffaroni (2010) as approximately 95%. More detailed information about the method to realize these maps are available in Fasolini (2014)...". Furthermore, we moved the information about the inventory of affected road sectors in "The study area" section of the paper, adding this paragraph: "...A detailed inventory map of the road sectors affected by shallow landslides in the study area was prepared and used as response variable of the model. The inventory map of the affected road traits include all the sectors hit by the shallow landslides occurred in the study area during 27–28 April 2009, March/April 2013 and 28 February–2 March 2014 rainfall events. For 2009 event, color aerial photographs at a resolution of 15 cm acquired immediately after the event were examined (Persichillo et al., 2017). For 2013 event, affected road traits were identified by visual interpretation of Pleiades satellite images with a resolution of less than 1 m (Persichillo et al., 2017). For 2014 event, slope failures and affected roads immediately after the event were detected through field surveys; the identified phenomena were mapped through a GPS tool, whose resolution is less than 2.5 m...". References: Fasolini, D.: La cartografia dell'uso e copertura del suolo: uno strumento per rilevare il cambiamento del territorio lombardo, Regione Lombardia e ERSAF, 76–87, 2014. Persichillo, M. G., Bordoni, M. and Meisina, C.: The role of land use changes in the distribution of shallow landslides, Sci. Total Environ. 574, 924–937, doi:10.1016/j.scitotenv.2016.09.125, 2017. Zaffaroni, P.: Confronto fra CLC 2006 e DUSAF 2.1 della Regione Lombardia, ASITA, Brescia 9–12 November 2010, 2010.

Comment 3 (ii) the discussion part must rewrote, at least the first 4 paragraphs.

Response to Comment 3 We modified the first four paragraphs of the "Discussions" section. This modified part was provided: "...In this work, a methodology able to classify, in different susceptibility classes, the traits of a road network potentially hit by sediments of landslides triggered above the road was developed and tested. Different Authors (Budetta, 2004; Hearn et al., 2008; Jaiswal et al., 2010a, 2010b, 2011; Quinn et al., 2010; Michoud et al., 2012; Tarolli et al., 2013; Bil et al., 2014, 2017; Penna et al., 2014; Ramesh and Anbazhagan, 2015; Tarolli and Dalla Sofia, 2016; Winter et al., 2016; Donnini et al., 2017; Pellicani et al., 2017; Postance et al., 2017; Martinovic et al., 2018) developed similar approaches in other geological/geomorphological settings, basing on the implementation of data-driven techniques for the estimation of road susceptibility. Data-driven models, that are based on the statistical relationships between predictors and response variables, depend strictly on the reliability of the inventories of the response variable (Guzzetti et al., 2006; Corominas et al., 2014). Besides this limitation, data-driven are most flexible to be used at different scales of analysis (from site-specific to regional scale) and do not require a lot of data not easily to be estimated as for the physically-based models (Corominas et al., 2014). For the first time, the proposed methodology allowed to implement a data-driven technique (GAM method) able to take into account also for the non-linear relationships between the predictors and the response variable (road sector hit by shallow landslides). In particular, the models some of the input predictors as non-linear variables (in this case, slope curvature, catchment slope, topographic wetness index, distance from shallow landslides source area, index of connectivity), understanding better the complex relationships which are present in an area between predisposing factors and susceptible roads (Philips, 2006; Goetz et al., 2011). Moreover, before building the model, the individuation of the most important predictor variables among the generally used predisposing factors leads to improve the knowledge about mechanisms which regulate the location of the damaged roads in such an area, avoiding for collinearity and bias that could reduce the reliability of the susceptibility estimation (Farrar and Glauber, 1967; Hosmer and Lemeshow, 1990; Bai et al., 2010). The robustness of the proposed methodology was also confirmed by the low confidence degree measured for the created models (Petschko et al., 2014). The first reconstructed susceptibility model (Model 1) takes into account for the most important predisposing factors in the study area, chosen among those morphological, hydrological and geological parameters taken into account for these analyses in different contexts by other Authors (Budetta, 2004; Jaiswal et al., 2010a, 2010b, 2011; Quinn et al., 2010; Michoud et al., 2012; Bil et al., 2014, 2017; Penna et al., 2014; Ramesh and Anbazhagan, 2015; Pellicani et al., 2017). The reliability of the model is quite fair, as testified by its AUC value (0.73) and by its high value of FP and TN indexes (22.3 and 45.8%, respectively). According to Model, most susceptible road segments are those located downstream to slopes characterized by high slope gradient (> 20°), limited height (< 50 m) and with shallow landslides triggering zones located very close to the road network (40-100 m). These settings are very widespread in the entire study area (Bordoni et al., 2015; Persichillo et al., 2016, 2018), but these particular features are not enough to discriminate more accurately those routes where damages provoked by sediments mobilized by shallow landslides are probable...". In these paragraph, following references will be added to the revised version of the paper: Bil et al. (2017): Bil, M., Andrasik, R., Kubecek, J., Krivankova, Z. and Vodak, R.: RUPOK: An online landslide risk tool for road networks, in: Advancing culture of living with landslides, edited by: Mikos, M., Vilimek, V., Yin, Y., and Sassa, K., Springer, Cham, 19-26, 2017. Donnini et al. (2017): Donnini, M., Napolitano, E., Salvati, P., Ardizzone, F., Bucci, F., Fiorucci, F., Santangelo, M., Cardinali, M. and Guzzetti F.: Impact of event landslides on road networks: a statistical analysis of two Italian case studies, Landslides 14, 4, 1521–1535, doi:10.1007/s10346-017-0829-4, 2017. Hearn et al. (2008): Hearn, G., Hunt, T., Aubert, J. and Howell, J.: Landslide impacts on the road network of Lao PDR and the feasibility of implementing a slope management programme, South East Asia Community Access Programme (SEACAP), Department for International Development, United Kingdom. Martinovic et al. (2018): Martinovic, K., Gavin, K., Reale, C. and Mangan, C.: Rainfall thresholds as a landslide indicator for engineered slopes on the Irish Rail network, Geomorphology 306, 40-50, doi:10.1016/j.geomorph.2018.01.006, 2018. Penna et al. (2014): Penna, D., Borga, M., Aronica, G. T., Brigandì, G. and Tarolli, P.: The influence of grid resolution on the prediction of natural and road-related shallow landslides. Hydrol. Earth Syst. Sci. 18, 6, 2127–2139, doi:10.5194/hess-18-2127-2014,

2014. Postance et al. (2017): Postance, B., Hillier, J., Dijkstra, T. and Dixon, N.: Extending natural hazard impacts: an assessment of landslide disruptions on a national road transportation network, Environ. Res. Let. 12, 1, 14010, doi:10.1088/1748-9326/aa5555, 2017. Tarolli et al. (2013): Tarolli, P., Calligaro, S., Cazorzi, F. and Dalla Fontana, G.: Recognition of surface flow processes influenced by roads and trails in mountain areas using high-resolution topography, Eur. J. Remote Sens. 46, 176–197, doi:10.5721/EuJRS20134610, 2013. Tarolli and Sofia (2016): Tarolli, P. and Sofia, G.: Human topographic signatures and derived geomorphic processes across landscapes, Geomorphology 255, 140–161, doi:10.1016/j.geomorph.2015.12.007, 2016. Winter et al. (2016): Winter, M. G., Shearer, B., Palmer, D., Peeling, D., Harmer, C. and Sharpe J.: The economic impact of landslides and floods on the road network, Procedia Eng. 143, 1425-1434, doi:10.1016/j.proeng.2016.06.168, 2016. Other references present in this correction are already inserted in the manuscript.

Comment 4 (iii) please change the Fig. 9, in order to make it representative according to the associated legend;

Response to Comment 4 We modified this figure for improving its comprehension. Modified Figure 9 was attached to these responses.

Comment 5 and (iv) try to find other color for the roads (at least in the Figures 1, 3, and 9) for increasing the contrast and readability of the map.

Response to Comment 5 We modified the colors of road network in Figures 1 and 3 to improve its visualization. Modified Figures 1 and 3 were attached to these responses.

Comment 6 Other minor problems you will find in the *.pdf file attached..

Response to Comment 6 We thank the Referee also for these suggestions. We considered all these minor revisions proposed by the Referee and we will insert them in the modified version of the manuscript.

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-

2017-457, 2018.

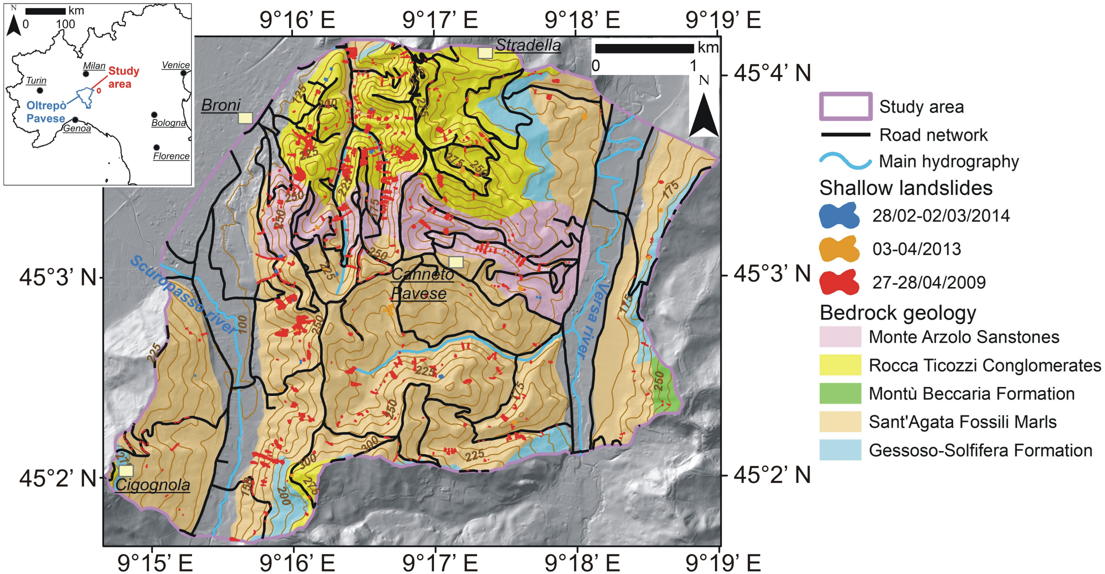

Fig. 1. Modified Figure 1 of the manuscript

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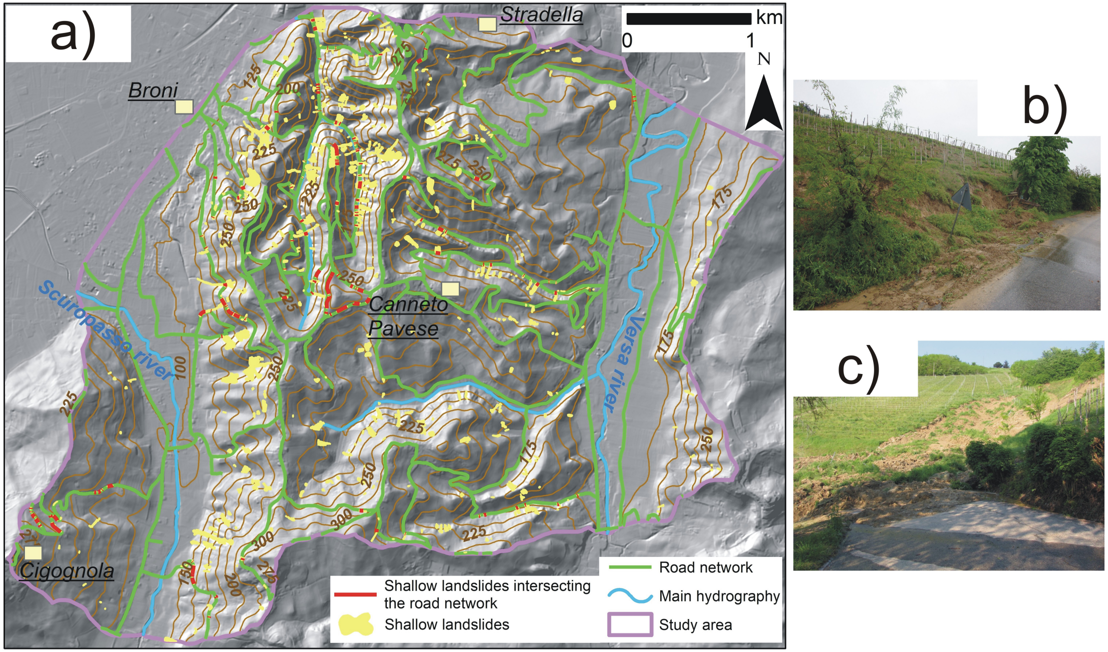

Fig. 2. Modified Figure 3 of the manuscript

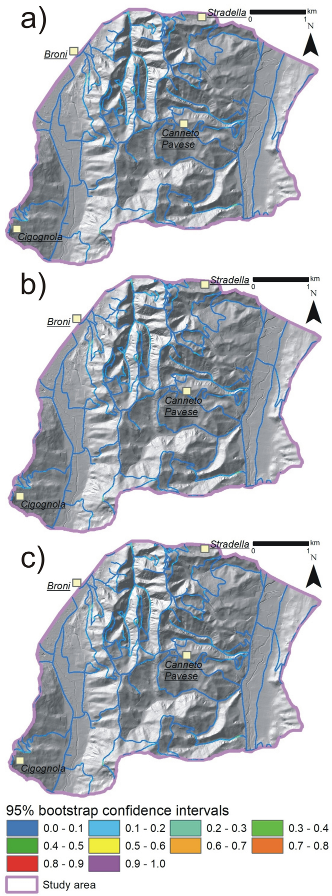

Fig. 3. Modified Figure 9 of the manuscript

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