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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Assessment of physical vulnerability of buildings and analysis of landslide risk at the municipal scale – application to the Loures municipality, Portugal" *by* C. Guillard-Gonçalves et al.

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General comments:

The paper presents a methodology for landslide vulnerability and risk assessment of buildings applicable at municipal scale. The topic addressed is scientifically relevant, of interest for the research community, and within the scope of NHESS. The scientific approaches and methods are valid; however, the obtained results are not discussed in a balanced, comprehensive way. The effort of measuring variability around the expert-

based estimate of the mean vulnerability values is not innovative but commendable; however, it is not clearly explained how this measure of dispersion relates with uncertainty and how the latter is defined. The paper would also benefit greatly if the basic assumptions and limitations of methods are clearly explained and interpreted in relation to each component of the risk analysis framework (i.e. vulnerability, hazard, economic value). Moreover, to maximize the significance of the research, I strongly suggest writing the Results and Discussion sections separately, so that the synthesis and interpretation of the most important findings, description of study limitations and implications, including future research recommendations are better addressed. The presentation quality of data and results can also be improved with minimum of effort. Lastly, the level of English is generally good; however the language and use of some expressions is sometimes ambiguous. If possible, please ask a native speaker to review the text. Given these considerations (as well as the specific comments & technical corrections below), I suggest the paper to be reconsidered for publication in NHESS after major revisions.

We acknowledge the remarks of the reviewer and the pertinent comments and suggestions he/she made along the work, which will allow increasing the quality of the final manuscript. It is true that the main topic of the research is not totally original. Nevertheless, we will improve the originality of the study with two interpretations of the questionnaire that support the vulnerability matrix instead of one. Indeed, in the new version of the manuscript, we will present the vulnerability assessed by the 14 landslide experts who know the study area, and we will compare the results with the ones we already have and which were calculated from the answers of the 52 landslide European experts. The risk will also be computed and mapped with the vulnerability assessed by the 14 landslide experts who know the study area and compared with the previously obtained results. In the new version of the manuscript, the uncertainty will be defined, and the term "variability" will replace the term "uncertainty" where necessary. Basic assumptions about the methods will be highlighted in the new version of the Introduction section and limitations of methods will be argued in the new Discussion section. The

new version of the manuscript will have two separate sections, one with the results, and the other one with the discussion, as suggested by the reviewer. Moreover, the presentation of the results will be increased adding a table showing the risk per civil parish. Finally, the manuscript will be send again to an English native speaker, and we will ask her to focus on the ambiguous expressions pointed by the reviewer, in order to make them more understandable.

Specific comments:

Abstract:

1. The abstract is concise and reflects the summary of the paper. However, it lacks a short interpretation of the most important finding (also for hazard and vulnerability) and the main conclusion. Please simplify and reduce the text where necessary (e.g. "the economic value of the buildings of...was calculated" can be reduced to "the economic value was calculated. . .")

We acknowledge the remarks of the reviewer. In the new version of the manuscript we will add a short interpretation of the most important finding (also for hazard and vulnerability) and the main conclusion. The text will be simplified and reduced where necessary.

2. The use of standard deviation to measure the variability of the mean vulnerability value in expert-based studies is not innovative: see Winter et al. 2014, An expert judgment approach to determining the physical vulnerability of roads to debris flow, Bull. Eng. Geol. Environ. 73: 291 – 305, DOI 10.1007/s10064-014-0570-3. Please consider referencing this resource

We acknowledge the remark of the reviewer and we will reference the advised resource in the new version of the manuscript.

3. Line 8: "The generalization of the vulnerability to the smallest statistical subsection was validated. . ." – it is not very clear what it is meant by "generalization of vulner-

ability"; the results of the first method can only be compared with the results of the second, more precise one (not validated, since these are no real observations, but model outputs as well)

We acknowledge the remark of the reviewer. We will reformulate the sentence in the new version of the manuscript to make it clearer. In fact, we applied a single method to assess physical vulnerability of building that was applied to two different terrain units: the Basic Geographic Entities (BGRI-subsection) and the individual buildings.

Introduction:

4. Line 19 – 20, p.5548: Landslides do not need to occur in constructed areas to cause damage, it is sufficient to impact them to result in economic loss

We acknowledge the remark of the reviewer. We will reformulate the sentence in the new version of the manuscript to make it more accurate.

5. This section needs to be better structured, paragraphs better related, language clearer; for example, lines 9 – 21, p.5549: landslide types, predisposing and triggering factors, as well as position of the elements at risk are discussed in a rather superficial manner and without relating them clearly with landslide vulnerability; line 18 - it is not obvious what is meant by "effects" of elements at risk position and why is this a source of uncertainty

We acknowledge the remark of the reviewer. In the new version of the manuscript, we will better structure this section, especially the part comprised from the line 9 to the line 21, clarifying the components of risk (hazard, vulnerability and economic value), and also the main methodologies to assess physical vulnerability and corresponding drawbacks. The term "effects" will be changed for "damage".

6. Key terminology needs to be clearly defined and referenced from the onset (e.g. risk, hazard, uncertainty, element at risk value)

We acknowledge the remark of the reviewer. We will add definitions from the onset of

the terms landslide risk, landslide hazard, uncertainty and element at risk value in the new version of the manuscript to make it more accurate.

7. Lines 22 – 29, p.5549: the study of Papathoma-Köhle et al. 2007 states that buildings were assessed only in the medium and high susceptibility areas not mainly because the data were scarce – as this paper states, but also “for the ease of demonstration” (see original paper, p. 767). The methodology was applied in Lichtenstein, a community in the Swabian Alb and not at regional scale – the spatial scale this paragraph is discussing. Please be precise and clear while referencing and making assertions. The concluding sentence in this paragraph refers to landslide risk, although this hasn’t been addressed so far (what do you mean by “in its whole”?)

We acknowledge the remark of the reviewer. In this section we have done by mistake two wrong assertions about the work of Papathoma-Köhle et al. (2007). In the new version of the manuscript this example will be deleted, and the ideas about the quantity of data and scale of analysis in the vulnerability studies will be clarified.

8. Lines 7 – 9, p.5550: please reference the original author of the vulnerability definition used in this study (and not a research project, who adopted it as well from the same author)

We acknowledge the remark of the reviewer. We will change the reference to Varnes and the IAEG Commission on Landslides and other Mass-Movements (1984) as advised in the new version of the manuscript.

9. Line 4, p.5550: “many vulnerability models. . .” – the paper mentions uncertainty in vulnerability models that have not yet been presented/described

We acknowledge the remark of the reviewer. The introduction section in the new version of the manuscript will be reorganized in order to solve the problem pointed out by the reviewer.

10. Line 11, p.5550: landslide intensity and magnitude are not synonymous (see Li

et al. 2010, Quantitative vulnerability estimation for scenario-based landslide hazards, Landslides 7:125 – 134, DOI 10.1007/s10346-009-0190-3)

We agree that landslide intensity is not synonymous to landslide magnitude. The phrase will be rewritten as "intensity and magnitude" (as in the original Safeland 2012). Moreover, in the new version of the Introduction section, we will clarify the concepts of landslide magnitude and landslide intensity on the base of various references (Lee and Jones, 2004; Li et al., 2010; Uzielli et al., 2015).

Lee EM, Jones DKC (2004) Landslide risk assessment. Tilford, London Li, Z., Nadim, F., Huang, H., Uzielli, M. and Lacasse, S.: Quantitative vulnerability estimation for scenario-based landslide hazards, Landslides, 7(2), 125–134, doi:10.1007/s10346-009-0190-3, 2010. Uzielli, M., Catani, F., Tofani, V. and Casagli, N.: Risk analysis for the Ancona landslideâĂŤII: estimation of risk to buildings, Landslides, 12(1), 83–100, doi:10.1007/s10346-014-0477-x, 2015.

11. Line 24, p.5550: “Some few. . .” – can you support this assertion with a referenced study or investigation results?

Examples of quantitative vulnerability assessment were already given in the original manuscript. However, the sentence will be rewritten in order to make the idea clearer.

12. Line 20 – 23, p.5551: The authors seem to disregard the fact that methods used in vulnerability assessment can and should be selected according to the scope of the study (incl. the level of spatial detail requested). Regional multi-dimensional vulnerability assessments can be performed using qualitative or semi-quantitative models in which uncertainty can also be addressed

We acknowledge the importance of scope of the study and the scale that controls the level of spatial detail requested, and this topic will be included into the manuscript. We also agree that regional multi-dimensional vulnerability assessments can be performed using qualitative or semi-quantitative models in which uncertainty can also be

addressed. However, our paper does not address the multi-dimensional vulnerability assessment (but only the physical vulnerability of buildings) and because of that we consider not necessary to develop this topic.

13. Line 25, p.5551: “municipal or regional scale” – “or” implies the two are synonymous (see line 12, p.5552 as well)

We acknowledge the remark of the reviewer and we will correct as advised in the new version of the manuscript, replacing "regional scale" by "municipal scale" along the complete manuscript.

14. The synopsis of literature can be improved; please write a brief summary of the most relevant studies for building risk to landslides as well; please indicate limitations and research gaps in previous research this study will address

We acknowledge the reviewer suggestion. In the introduction section, a brief summary of the most relevant and recent studies about building vulnerability and risk assessment will be introduced, as well their main limitations. We consider this work as a contribution to fulfil a research gap on the physical vulnerability assessment based on expert opinion, and this will be stated in the new version of the manuscript.

Study area:

15. Please indicate if damages to built environment have been registered in the area in the past; also, a short characterization of the building stock and landslide types would help the reader to better understand the potential risk context

We acknowledge the remarks of the reviewer. We will add information about damages to built environment, building stock and landslides.

16. Line 19, p.5552: Please indicate the complete reference source We acknowledge the remark of the reviewer and we will complete the reference source in the new version of the manuscript.

Data and methods:

17. Please consider shortening and simplifying the title of each sub-section. It would be helpful if the methodological steps (from vulnerability assessment to risk analysis) can be explained in a short paragraph at the onset of the section

We acknowledge the remarks of the reviewer. In the new version of the manuscript, we will shorten the titles of the sub-sections, replacing them by these new titles:

3. Data and methods 3.1. Frequency-Magnitude of the landslides, susceptibility and hazard 3.1.1. Frequency-Magnitude relationship 3.1.2. Annual and multiannual spatio-temporal probabilities 3.2. Physical vulnerability of the buildings 3.2.1. Vulnerability matrix 3.2.2. Vulnerability based on statistical mapping units 3.2.3. Vulnerability based on fieldwork building inventory 3.3. Economic value of the buildings 3.4. Landslide risk

Moreover, we will insert a short paragraph at the onset of the section, explaining the methodological steps from landslide susceptibility to risk analysis.

18. Line 11, p.5553: please indicate the velocities associated with each landslide type According to Cruden and Varnes’ (1996) classification, most of the landslides in the study area were slow (shallow slides), very slow or extremely slow (deep-seated slides). This information will be provided in the study area section.

19. Line 19 - 25, p.5553: age, number of floors, structural type, etc. are not proxies for building foundation but indicators of building resistance capacity or susceptibility of being damaged due to the impact of a landslide We acknowledge the remark of the reviewer; we will reformulate the sentence to make it more accurate in the new version of the manuscript.

20. I suggest to write the paragraph describing landslide types and hazard intensity scenarios and proxies (depth of slip surface, height of accumulated material) before the vulnerability matrix section

We acknowledge the remark of the reviewer; we will follow the suggestion of the re-

viewer reordering the text in the new version of the manuscript.

21. Line 7, p.5554: what do you mean by "typical landslide parameters"? Please argue clearly why those nine landslide scenarios were selected (and no other slip surface depths or accumulation heights), and what building damage patterns are expected or can be associated with each scenario (check the relevant literature for observations on different structural building types)

The maximum values considered for both the depth of the slip surface and the heights of affected material were defined taking into consideration the largest landslides inventoried in the study area (Zêzere, 2002; Zêzere et al., 2008). The remaining scenarios use standard values considered in landslide classifications (e.g. Záruba and Mencl, 1980). Existing relationships between building damage patterns and height of affected material for debris flows (e.g. Papathoma-Köhle et al., 2012) cannot be applied to the study area as landslide types and velocities are not comparable. This explanation will be included in the new version of the manuscript.

22. Line 13, p. 5554: how relevant is to send such a specific questionnaire to experts in "other natural risks"?

We acknowledge the remark of the reviewer; all the interviewed experts already worked with landslides, even if it is not their principal field. We will reformulate the sentence to make it more accurate.

23. Line 9 – 11, p.5554: I suggest to rephrase describing differences between vulnerability models (quantitative vs. qualitative or semi-quantitative); the statement is too general

We acknowledge the remark of the reviewer. We will rephrase this part in the new version of the manuscript, distinguishing the different vulnerability models (quantitative vs. qualitative or semi-quantitative), and introducing a new reference (Ciurean et al., 2013).

Ciurean, R. L., Schröter, D. and Glade, T.: Conceptual Frameworks of Vulnerability Assessments for Natural Disasters Reduction, in Approaches to Disaster Management - Examining the Implications of Hazards, Emergencies and Disasters, Tiefenbacher, J. (ed.), InTech., 3-32, 2013.

24. Please argue the use of slip surface depth as proxy for landslide destructive capacity/ intensity (see also comment 10 for the use of landslide magnitude vs intensity)

In fact, we use the slip surface depth as a proxy for landslide destructive capacity instead of the landslide velocity that typically defines the landslide intensity. Our option was guided by the following reasons: The landslides affecting the study area have generally slow- very slow – extremely slow velocities. In this context, we consider that landslide velocity is not the most appropriate parameter to assess the landslide destructive capacity. Moreover there is no instrumentally data about the velocities of each landslide. On the other hand, without relevant differences regarding landslide velocity, the depth of the slip surface is significant as a proxy for landslide destructiveness, namely through the comparison with the depth of the building foundation. In addition, it is possible to find a statistic relationship between the landslide slip surface depth and the landslide area, which is an accurate landslide morphometric parameter available in the landslide inventory.

We acknowledge the remark of the reviewer; we will add this remark in the new version of the manuscript.

25. I suggest to add the questionnaire (matrix) as annex to the paper, if there is no sufficient space in this section

We acknowledge the remark of the reviewer; we will add the matrix in Annex in the new version of the manuscript.

26. Standard deviation is a measure of variability around the estimate of the mean vulnerability value; this shows how much the experts were in (dis-)agreement about

the vulnerability of a building type for a given hazard scenario; however, it does not give any indication of the accuracy of their answers (i.e. how close where they to the real, true value given their different backgrounds (see comment 22), etc. Please define clearly what you mean by “uncertainty” and to which extent you are able to address it (from the onset – Introduction)

We acknowledge the remark of the reviewer; we will change the text in the new version of the manuscript, explaining that the standard deviation values measure the variability of the answers more than the uncertainty.

27. Line 14 – 19, p.5555: The classification of the building stock should be described in detail at the onset of the vulnerability section; what do you mean by “type of construction”? We acknowledge the remarks of the reviewer; we will describe the classification of the buildings on the onset of the section and we will replace “type of construction” by “structural type” to make it clearer in the new version of the manuscript.

28. Line 24, p.5555: Please indicate a mathematical expression for the calculation of the weighted average vulnerability per BGRI-subsection We acknowledge the remarks of the reviewer; we will add a mathematical expression for the calculation of the weighted average vulnerability per BGRI-subsection in the new version of the manuscript.

29. Line 1-2, p.5556: Can you give an indication (relative or absolute number) of what you mean by “most (of the BGRI)” and “large (number of buildings)”? We acknowledge the remarks of the reviewer; in the new version of the manuscript, we will add an indication about what “most of the BGRI” and “large number of buildings” mean, specifying that “56% of the BGRI have only one structural building type and 30% have two structural building types”.

30. Line 7-8, p.5556: please modify the text in accordance with suggestions from comment 26 We acknowledge the remark of the reviewer; we will change the word “uncertainty” for “variability” here and in other parts of the text, in the new version of

the manuscript.

31. Line 16, p. 5556: please state clearly what are the “relevant building characteristics” We acknowledge the remark of the reviewer; we will state clearly what are the “relevant building characteristics”, in the new version of the manuscript.

32. Section 3.1.3: This sub-section should focus on the method of field data collection, the selection criteria of building characteristics, the vulnerability assessment model (method) used

We acknowledge the remark of the reviewer; from what we understand, it was not clear that the method was the same, only the inventory changed. To make it clearer, in the new version of the manuscript, we will explain that we assessed the physical vulnerability on the test site using the same method, but that the vulnerability was attributed to each building instead of being calculated per BGRI.

33. Line 19, p. 5556: what do you mean by “type of urbanization”? We acknowledge the remark of the reviewer. We reconsidered the text; the meaning of the sentence being not correct, we will delete it in the new version of the manuscript.

34. Line 23 – 24, p. 5556: there are two methods (with different mapping units) in one single study and not two studies

We acknowledge the remark of the reviewer. We will replace “study” by “approach” in the new version of the manuscript.

35. Line 24, p. 5556: please replace the term “cost-benefit ratio” with a less pretentious one if an actual cost-benefit analysis is not performed

We acknowledge the remark of the reviewer. We reconsidered the text and we will delete this sentence in the new version of the manuscript.

36. Line 20, p.5558: rotational (deep-seated and shallow) landslides? We acknowledge the remark of the reviewer; we will add “(deep-seated and shallow rotational and

translational slides)" in the new version of the manuscript in order to make it clearer.

37. Line 24, p.5558: please indicate the mathematical function characterizing the relationship between the landslide depth and area, and explain the similarities between the two landslide datasets

We acknowledge the remarks of the reviewer. We will add the mathematical function (AL = 706×d) characterising the relationship between the landslide depth and area in the new version of the manuscript. Moreover, we will explain that the landslides of Garcia's area are similar than the ones of Loures municipality "in terms of landslide types and volumes".

38. Lines 3 – 5, p.5560: please indicate the reference sources We acknowledge the remark of the reviewer; we will add the reference sources in the new version of the manuscript.

Results and discussion:

39. I strongly suggest to split this section in two (one for the results, the other, an extensive discussion and interpretation of the results)

We acknowledge the remark of the reviewer; we will split this section in two, one named Results and the other named Discussion in the new version of the manuscript.

40. The knowledge of the study area is maybe less important as the research background and experience of the interviewed experts; please state their research background

We acknowledge the remark of the reviewer; we added information about the experts: "who have a research background or some experience in the landslide field"

41. Lines 1-2, p.5562: one would expect that a wooden or metal building impacted by a 5 m landslide material would actually be totally damaged (or associated with an average vulnerability higher than 0.94). Can you please discuss the expert based

values in relation with the vulnerability values estimated in the literature for the same type of structural buildings?

We understand the concern, but the reviewer has to keep in mind that these landslides are not debris flows and the answer is related with their slow/extremely slow velocity. Looking on the new obtained data, in terms of accumulated material height, the landslides that have a 5 m height of accumulated material produce an average damage for the four structural building types corresponding to a vulnerability of 0.91. For comparison, the vulnerability curves computed by Papathoma-Köhle et al. (2012b) using a Weibull distribution show that debris flows produce a total destruction (vulnerability = 1) when the accumulated material reach 3.5 metres height. Considering that the debris flow intensity is increased by its velocity, it is understandable that its damage potential is higher than the damage potential of the slow landslides considered in the present study. This topic will be included in the new discussion section of the manuscript.

42. Table 2: do vulnerability values represent the upper bound associated with each damage class? If so, what is the lower bound? We acknowledge the remark of the reviewer; we completed the Table 2 adding the lower bound, and we specified in the text that "Each damage class was associated to the corresponding upper bound of its corresponding physical vulnerability (Table 2)."

43. Lines 6 – 9, p.5562: what would be the implications of these results for the final calculation of risk?

Implications for final calculation of risk may be very relevant. For example, taking a building type SBT1, with a value =100,000 euros, affected by a 0.5m landslide accumulated material located in the highest landslide susceptibility class, the annual risk is 33.6 euros considering the average vulnerability, but may range between 18 and 49 euros considering the Standard Deviation value, which means a difference of 46% to average value. This example will be included in the discussion section in new version of the manuscript.

44. Section 4.1.2: The interpretation of results is very crude. Please be more specific in explaining the differences in vulnerability values associated with each damage stage and depth of slip surface/accumulated material height (see also comment 24)

We acknowledge the reviewer comment. In the new section of the Discussion the differences between the vulnerability values and the corresponding damages and depth of the slip surface/accumulated material height will be introduced and the results will be better discussed.

45. The literature on buildings vulnerability assessed using height of the accumulated material and structural type can be consulted and used here for comparison

We acknowledge the remark of the reviewer. In terms of accumulated material height, the landslides that have a 5 m height of accumulated material produce an average damage for the four structural building types corresponding to a vulnerability of 0.91. For comparison, the vulnerability curves computed by Papathoma-Köhle et al. (2012b) using a Weibull distribution show that debris flows produce a total destruction (vulnerability = 1) when the accumulated material reach 3.5 metres height. Considering that the debris flow intensity is increased by its velocity, it is understandable that its damage potential is higher than the damage potential of the slow landslides considered in the present study. We will integrate this comparison in the discussion section of the new version of the manuscript.

Papathoma-Köhle, M., Keiler, M., Totschnig, R. and Glade, T.: Improvement of vulnerability curves using data from extreme events: debris flow event in South Tyrol, Natural Hazards, doi:10.1007/s11069-012-0105-9, 2012.

46. Section 4.1.3: the reader does not know what method (empirical, heuristic, numerical ,etc.) was used to compute vulnerability at individual building level nor what indicators (building characteristics) were incorporated into the model (how where the vulnerability values at building level obtained?); thus, the comparison with the BGRIscale method is ineffective and the assertion of accuracy validation for the first method ques-

tioned.

We acknowledge that we were not clear enough in the description of the vulnerability method at individual buildings. In the “Data and methods” and in the “Results” sections we will better explain that the physical vulnerability of the test site was assed using the same vulnerability matrix presented in the expert questionnaires. In the individual buildings approach, the vulnerability was attributed to each single building instead of being calculated per BGRI. With this approach, we will evaluate the influence of the mapping unit in the final result of buildings physical vulnerability. In fact the vulnerability assessment method is only one (expert opinion using vulnerability matrices) for both vulnerability approaches at the BGRI statistical units and at the building scale.

47. The use of the Cartesian system is confusing; I suggest to split Fig. 8 and Fig. 15 in two, and actually use the Y-axis for the slide slip surface depth values and material height separately, or inverse the two parts of the graph, showing on the negative Y axis the depth of slip surface, and on the positive Y axis the height of material. Please also check the correctness (completeness of Fig. 8), the inter-quartile ranges seem to miss the median line and one box is even missing.

We acknowledge the remark of the reviewer; we will inverse the two parts of the graph as suggested, showing on the negative Y axis the depth of the slip surface, and on the positive Y axis the height of material, in the new version of the manuscript. The correctness has been checked; most of the time, the median overlap one of the inter-quartile, and that is why it didn’t appear. Thus, the value of the median is indicated on the Figures 8 and 15. Moreover, the “missing box” is due to the fact that the median and the 2 other inter-quartiles have the same value.

48. Line 3, p.5564: what do you mean by “reproducible”? What we mean be “reproducible” is that it can “easily be applied to other areas, because the data are available in the census”. We will change the sentence in the new version of the manuscript.

49. Please indicate the source of Fig. 10 in the caption as well; the same for Fig. 11

and 12 (indicating they are based on the work done by Guillard and Zezere, 2012) We acknowledge the remark of the reviewer and we will indicate the source in the captions of Fig.10, 11. and 12 (based on the work done by Guillard and Zezere, 2012).

50. Section 4.3.2 (and associated figures/tables): decimal numbers should be limited to maximum 2. Where necessary, use scientific notation (negative exponent of 10 for very small numbers)

We acknowledge the remark of the reviewer. In the new version of the manuscript, we will use the scientific notation in the text, in the Tables 7 and 8, and we will keep only 2 decimal numbers in the Figure 11.

51. Lines 9 – 12, p.5566: Please explain the implications of the methodological limitations for the risk calculation

Discussion on the implications of the methodological limitations for the risk calculation will be included in the discussion section.

52. Section 4.4: Fig. 13: please use the notation Risk (Cpixel) and indicate the pixel size in caption

We acknowledge the remark of the reviewer. We will use the notation Risk (€ per pixel) in the legend of the Fig. 13., 14. and 16., and we indicated the pixel sixe (5 m) in the captions of these figures, in the new version of the manuscript.

53. Wasn't there any information loss during the transformation of buildings from vector to raster? How does that influence the risk estimates?

We acknowledge the remark of the reviewer. As expected, there is information loss during the transformation of buildings from vector to raster, as in any vector to raster transformation. We calculated the total area of the buildings in the vector and in the raster to have an idea of the loss of area, and we found that the total building area of the raster is 9.00 km2, and the total area of the buildings in vector is 9.25km2. The 0.25 km2 which were lost during the transformation from vector to raster represent only

2.7% of the total area of the buildings, thus, even if the transformation changes slightly the shape of the buildings, their surface is almost the same, what has little influence on the risk estimates. We will insert this information in the text, section 4.4, in the new version of the manuscript.

54. Fig. 15: please indicate the value of the outliers in the figure caption as well We acknowledge the remark of the reviewer. We will indicate the maximum outlier values in the caption of the Fig. 15, in the new version of the manuscript.

55. Please consider increasing the size of figures 13, 14, 16 We acknowledge the remark of the reviewer and we will indicate to the editor that the size of the Fig. 13., 14. and 16. should be increased.

56. It is rather difficult to relate with economic risk at pixel size only; I suggest, if possible presenting the risk associated with different time period for each civil parish as total economic risk per administrative unit (since at BGRI-subsection it might be too time consuming). This way a comparison at administrative level might be easier to evaluate and interpret

We acknowledge the remark of the reviewer. We calculated the risk for each civil parish and will add the new results in a new table (Table 9), in the new version of the manuscript.

Conclusions:

57. Part of the text under this section belongs to a discussion section (with much more in depth interpretation and considering the suggestions above)

We acknowledge the remark of the reviewer. We will put part of this section in the Discussion section in the new version of the manuscript.

58. Line 1 – 3, p. 5569: if the value of building's content is included in the assessment, it might change significantly the modeled vulnerability value but the real capacity of the building to resist the impact of a landslide would be the same; therefore I don't consider

the exclusion of contents value in the analysis a limitation

We agree that the value of the building's content is not a limitation for the vulnerability assessment. Nevertheless, it remains a limitation for the analysis of the landslide risk, because the element at risk value is part of the risk, and the value of the building's content is part of the element at risk value.

59. Please indicate the significance of the contribution of this study to the research field and possible practical applications

The contribution of this study to the research field and possible practical applications for different end users will be addressed in the Concluding Remarks section of the new version of the manuscript, considering the needs of Spatial Planning, Civil Protection and Insurance Companies.

- Please consider rephrasing the ambiguous or imprecise expressions in the text: e.g. line 1, p.5548: "the study offers", line 9, p.5548: "expensive damage", line 19, p.5549: "course of landslide", line 29, p.5549: "analyzed in its whole", "building belonging to a landslide body", etc. (please ask a native English speaker to review the text)

We acknowledge the remark of the reviewer. We will send the text again to a native English speaker, insisting for him to review the imprecise expressions in the text: e.g. line 1, p.5548: "the study offers", line 9, p.5548: "expensive damage", line 19, p.5549: "course of landslide", line 29, p.5549: "analyzed in its whole", "building belonging to a landslide body".

- Please look through all figure captions and simplify them if possible We acknowledge the remark of the reviewer and we will simplify the figure captions when possible (especially for the Fig. 8, Fig. 15), in the new version of the manuscript.

Technical corrections: - Faulty referencing style: line 24, p.5548: Varnes and IAEG, 1984 We acknowledge the remark of the reviewer and we will correct the referencing style in the new version of the manuscript, replacing "Varnes and IAEG, 1984" by

"Varnes and the IAEG Commission on Landslides and other Mass-Movements, 1984"

Interactive comment on Nat. Hazards Earth Syst. Sci. Discuss., 3, 5547, 2015.