

RC1

Dear Dr. Tiberiu-Eugen Antofie and team

thank you for the revisions you have made to this manuscript. Here are some minor comments that I would still like you to consider to improve the readability of this paper.

Specific comments

- Line 51, where it is mentioned that this study looks at multi-layer hazards, is a bit unexpected to the reader, as you mention the study before it has been introduced. It would be more clear to first introducing the study, before highlighting which definition of multi this study considers

AC: From lines 40-50, we first provide the context and describe two multi-hazard approaches. In line 51, we highlight our study's alignment with the multi-layer hazards definition. To address the reviewer's concern and improve clarity, we have slightly modified line 51 as follows: *In this context, our study aligns with the first definition of multi-layer hazards, as we examine the combined exposures of single hazards over a region, recognizing that hazard interrelations can result in an impact distinct from the sum of individual hazards exposures*

- Line 67 is still unclear to the reader. It gets explained in line 81-82, though I wonder if it can not just be stated more clearly in point 2. As ‘exposure relationships between assets and multiple hazards.’

AC: Correction considered at point 2 as suggested

- Line 96-104, excellent to have the research gap in the introduction, but this new piece of text feels a bit out of place. As this highlights research gaps, it should go much earlier in the introduction, before highlighting what the study is going to address, before the challenges. Perhaps together with the multi examples in Line 54-58

AC: Correction considered

- Line 268-269 reads a bit confusing, as it says ‘compared with city centers’ twice to say the same thing? Consider stating the statistics at the start of the sentence. ‘58% of commuting zones (FUA) are exposed to multi hazards, which is ... higher compared with city centers’

AC: Correction considered as suggested

58% of commuting zones (FUA), which is 257 out of 442, are more exposed to multi-hazards compared to city centers

- Line 523-529, it would make more sense to first discuss the outcome of the study and end with future research. The newly added future research appears unconnected to the rest of the text now.

AC: Correction considered as suggested. Ended with future research.

Technical comments

- Line 14, should 'develop' be 'developed' as It has been done in the past?

AC: Corrected as "are developing"

- Line 54-48, make two sentences for readability

AC: Corrected, two sentences made:

This is exemplified by events such as the Portugal wildfires and flash floods in October 2017, where these hazards occurred in relatively close succession, both affecting the same buildings and infrastructure or the floods. Similarly, the dam failure in summer of 2002 in Czech Republic when floods had caused significant damage to buildings, infrastructure, and agricultural land and subsequent dam failure added to the devastation, impacting structures that were already dealing with the effects of the floods.

- Line 187, the ESDA package, does this need a reference in the footnote? Can this not just be referenced at the end with a normal citation?

AC: Corrected, introduced as a reference:

Rey, S. J., Anselin, L. (2007). *PySAL: A Python Library of Spatial Analytical Methods*. *Review of Regional Studies*, 37(1), 5-27.

- Figure 7 still has risk instead of exposure in it.

AC: Corrected,

- Line 374, still says risk, not exposure

AC: Corrected,

RC2

Dear Authors,

Thank you for submitting a revised version of your manuscript which reflects the suggestions and comments proposed. Your considerable effort in providing additional explanations, clarifying misunderstandings, and answering important questions is much appreciated. However, some misunderstandings persist, particularly in relation to concepts like hazard and exposure, which have an important role in your research design and methodological approach. To address these, please can you add/reference the 'exposure' and 'hazard' definitions you use (including the extra explanation that natural events are only termed hazards when they have the potential to harm people or cause property damage, social and economic disruption, etc. and how this specific aspect influenced the methodological approach you proposed).

Below a list of further comments and suggestions:

In the Author's Response:

1. You argue that: 'clustering this data and then combining it through meta-analysis is more powerful compared with clustering natural phenomena (which are not hazards) and assets (buildings, population) that are not at risk or exposed (because they are not assessed against each other) and then combining them through the meta-analysis.'

RC: While I understand the reasoning, the work does not present any evidence of a comparison between the adopted approach and one in which the meta-analysis is performed after assets and hazards layers are combined. Therefore, the argument that the former approach is more powerful cannot be sustained.

AC: Thank you for your valuable feedback.

I would like to underline that there are numerous methodologies available for conducting multi-hazard analyses, each with its own strengths and contexts in which it is most effective. The approach we have chosen, which involves first clustering the components of risk (e.g, exposure to single hazards) before combining them through meta-analysis, is one of the well-established methodologies in the field. Please see below some articles reviews underscoring the importance of maintaining the integrity of individual components before their combination.

*Gallina, V., Torresan, S., Critto, A., Sperotto, A., Glade, T., & Marcomini, A. (2016). A review of multi-risk methodologies for natural hazards: Consequences and challenges for a climate change impact assessment. *Journal of Environmental Management*, 168, 123-132

*de Ruiter, M. C., Ward, P. J., Daniell, J. E., & Aerts, J. C. J. H. (2017). Review article: A comparison of multi-hazard risk frameworks. *Natural Hazards and Earth System Sciences*, 17(7), 1481-1493.

While it is true that a direct comparison between the two approaches was not performed in this study, the chosen methodology is grounded in established risk analysis practices.

2. In relation to the comment on cold-/hot-spots you provided the following explanation you state: 'while "clusters" generally refer to spatial groupings of similar values, "hotspots" / "coldspots" denotes area that exhibits statistically significant clustering, characterized by a z-score and a pvalue. When the p_vlaue is small and z_score is negative the area is defined as 'coldspot', when the p_vlaue is small and z_score is positive the area is defined as "hotspot". When the p-value is very small (we fixed the p_values < 0.10 in our study), it means it is very unlikely (small probability) that the observed spatial cluster is the result of random processes (so the spatial pattern denotes a statistically significant clustering).

RC: Please insert this explanation in the text.

AC: Inserted, lines180-185

3. In relation to the title of section 2.3, you state: We acknowledge the need for clarity regarding the distinction between 'multihazard potential' and the 'multi-hazard potential impact' so we are proposing the: multi-hazard potential of a region driven by exposure

RC: Another alternative may be: Meta-Analysis: Identifying regions with potential exposure to multi-Hazards

AC: Comment considered as suggested

4. In relation to comment 4 in the Discussion section, you state: In a previous version of the study we also exemplify the applicability of the methodological approach presented within the multi-hazard interaction theoretical framework developed by Gill and Malamud (2014). Please refer to

figures 2, to 11 from the publication for the multi-hazard interaction theoretical framework, which is not included as it will be the subject of a new study.

RC: It is not clear to me how Figures 2 - 11 in this manuscript relate with the methodological framework developed by Gill and Malamud (2014). I noted you removed the reference to this study in the manuscript, as it will be the subject of a new study (looking forward to reading it!), so please also remove the reference at lines 518 - 19 ('We also exemplify the applicability of the multi-hazard methodological approach within a multi-hazard interaction theoretical framework')

AC: Removed

Please also consider:

- Notation of figures in the text (e.g., line 365 versus 372)
- Missing information - line 376 (Island?)
- Inconsistencies: 'multi-hazard' vs 'multihazard'
- Line 491 - I still argue that the exclusion of assets' vulnerability characteristics is not a shortcoming but a research design choice

AC: *Most important shortcoming is that the presented case study does not consider the vulnerability (which was a considered aspect of the research design) for the assessment of the assets (population and residential built-up) exposed to multi-hazards.*

- Reformulating the last sentence in the Conclusions section not as an objective but a potential outcome ('The objective of this study is to support national authorities on addressing the multi-hazard approach in the National Risk Assessments preparation').

AC: All considered as suggested