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Reply on RC3

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Author comment on "Review article: A systematic review and future prospects of flood vulnerability indices" by Luana Lavagnoli Moreira et al., Nat. Hazards Earth Syst. Sci. Discuss., https://doi.org/10.5194/nhess-2021-34-AC4, 2021

- The authors analyze the state-of-the-art on flood vulnerability indices. They assess the different alternatives that have been used in each of the steps that comprise the process of constructing vulnerability indices, pointing out the characteristics and advantages and disadvantages of the methods used so far and highlighting the scientific gaps that remain to be addressed with respect to vulnerability indices. In general, the manuscript addresses in considerable detail the alternatives used in the different construction steps of vulnerability indices. Above all, I think that the most interesting contribution is the one related to uncertainty and sensitivity analysis and validation, as this is an aspect that needs more effort from the scientific community for its characterization.

A: We thank you for your positive and constructive comments. We addressed all comments and explained how the manuscript was modified in light of these suggestions.

- I think it would have been very interesting to also analyze the impact that the decision-making process has on the results obtained, since they usually have implications for flood risk management.

A: We agree that the decisions made during the vulnerability process can influence the outcomes, which in turn can influence risk management. We added a sentence on this in the discussion session (5 Persisting gaps and future research). If the reviewer thinks it is appropriate, we can further expand the discussion in this direction. The text reads: "Only 9.5% have conducted sensitivity or uncertainty analysis. This can lead to vulnerability outputs incoherent with the local reality, either over or underestimating the vulnerability. This in turn, has direct implications for flood risk management" (lines 328-329).

- Similarly, alternatives to improve the reliability of vulnerability indices are sometimes proposed, but they are explained in little detail in the text (sometimes they are simply mentioned).

A: Thanks for this suggestion. We modified the "5 Persisting gaps and future research" session and added more examples on how to improve the reliability of vulnerability indices.

For instance: "A better understanding of the linkages between urban-rural linkages is also needed instead of studying it in isolation. To this end, the framework proposed by Jamshed et al. (2020) could be used. This framework considers, either qualitatively or quantitatively, how rural-urban linkages can influence the occurrence of floods and how these shapes the vulnerability of rural households." (lines 275-278).

- On the other hand, the methodology used to collect information on vulnerability indicators was not considered in this paper. Indicators are obtained mainly through surveys or consultation of public databases and obtaining the information in one way or another partly conditions the choices that can be made later or, at least, limits the alternatives available at each stage of index construction. I think the authors should consider this for future works.

A: Thanks for this observation. We added this future research line as a suggestion in our discussion session: "Future reviews could also look into the methodology used to collect information on vulnerability indicators (e.g. survey, public databases) as this influences the choices that can be made at each stage of the index construction." (lines 344-345).

- Finally, I would have liked to have found a part of the text discussing the terminology used and how the theoretical framework also determines the methodological choices that are subsequently made when constructing vulnerability indices. The introduction (lines 29-38) gives a brief outline, but I think that this is one of the main challenges facing this field (i.e., standardization of the terminology used and of the concepts to be characterized and included when analyzing vulnerability to floods) and this should have been discussed in more detail.

A: We agree that this is a valuable contribution. We added the following paragraph to the discussion session: "Besides the aforementioned methodological gaps, it is important to emphasize that the theoretical framework adopted influences the methodological choices that are made when constructing vulnerability indices. Even though we have not analyzed the theoretical constructs used by each study, when reading the articles it became clear that several of them do not specify how they conceptualize vulnerability. Furthermore, there are ambiguities in how vulnerability is understood (Kelman, 2018). For instance, some authors consider coping and adaptive capacity as components of flood vulnerability (e.g. de Brito et al., 2018). Others include flood hazard characteristics or exposure (e.g. Carlier et al., 2018; Chaliha et al., 2012) as part of vulnerability. Hence, we argue that a stronger theoretical underpinning of research is needed for producing scientifically rigorous and comparable research. Within this context, future work could investigate how different terminologies and theoretical constructs are defined and applied across different flood vulnerability case studies." (lines 335-343).

- Line 25: I do not agree with the statement that 'vulnerability is a forgotten aspect in flood risk analysis today'. In fact, as mentioned in the abstract (line 9) and in the introduction (line 29), the characterization of vulnerability is an aspect that, in recent years, has aroused enormous interest within the scientific community due to the paradigm shift we are experiencing with regard to the flood risk analysis and management. On the other hand, I do agree that there is still a long way to go for a truly complete characterization of vulnerability, integrating all its components and dimensions and considering it as a dynamic component of risk (and not a static one, which is how it is usually considered today).

A: We agree with the comment and removed the expression "yet still neglected"

(line 29).

- Lines 59-61: It is true that there are no papers questioning the implications of the different choices made when constructing a vulnerability index in the context of flooding, but there are papers that address this issue in general for the construction of vulnerability indices, so I would include some reference here so that the reader is clearer about the context in which the work takes place and the scientific gaps addressed in it (Schmidtlein et al., 2008; Tate, 2012, 2013).

A: Thanks for pointing out to these references. They were added to the text: "Some studies also analyzed different methods and index construction designs to understand which decisions have the greatest influence on the vulnerability outcomes. For instance, Nasiri et al. (2016) compared several methods, including damage-curves, computer modeling and indicators to evaluate flood vulnerability. Similarly Schmidtlein et al. (2008) and Tate (2012, 2013) examined the sensitivity of the results to changes in the construction of the index." (lines 57-61).

- Lines 61-62: As I mentioned before, I would include some references, since there are indeed works that analyze vulnerability from a temporal point of view (as well as spatial), although not really in the context of floods, such as Cutter and Derakhshan (2020) and Cutter and Finch (2008).

A: In the text, we stated that there are no literature reviews that tackle how the dynamic aspects are considered. We did not mention that there are no articles that consider this aspect.

We modified the text to highlight this: "In addition, even though there have been recent advancements in the field (e.g. Cutter and Derakhshan, 2020), the temporal dynamics of flood vulnerability have not been tackled by the existing reviews" (lines 65-67).

- Lines 159-163: A distinction is made between works carried out in urban and rural areas; however, there is no definition of what is meant by rural and urban areas. I believe that the criteria considered to differentiate between the two areas should be specified, since they may be different in different parts of the world.

A: We agree that it is important to defined what we mean by this. We added a definition of rural and urban areas to the methodology session. It now reads: "Here, rural areas are defined as sparsely populated areas whereas urban areas are defined as densely populated regions."

- Lines 173-175: This is related to the general comment I made above. These types of variables can be included in vulnerability analyses when the information is obtained through surveys, since they are variables that cannot be measured directly and are very subjective (such as, for example, the one mentioned 'experience with floods'). There are cases in which proxy variables can be included, but they are usually far from the concept to be characterized.

A: Thanks for this observation. We added more information to explain this indicators: "Therefore, when dealing with flood vulnerability, other relevant indicators such as risk perception (Carlier et al., 2018), past flood experience (Beringer and Kaewsuk, 2018) are important. However, data on these are often not readily available, thus requiring local research, which demands time, financial resources and a multidisciplinary team." (lines 283-286).

- Lines 264-265: I think it would be clearer if a definition or some idea, in a very brief form, about the theoretical framework proposed by Jamshed et al. (2020) is included.

A: Thanks for the suggestion. We included a brief comment about this framework: "This framework considers, either qualitatively or quantitatively, how rural-urban linkages can influence the occurrence of floods and how this shapes the vulnerability of rural households. It considers rural areas not as secluded units, but rather as interlinked with cities." (lines 276-278).

- Line 275: The use of Google Trends and, above all, of social networks such as Twitter could be included as additional indicators. However, to mention that the use of these tools could be an alternative to the analysis of the population's risk perception is misleading. Not all areas of the world have access to technology and, therefore, to these types of tools (especially social networks). Therefore, I believe that the simple fact of being able to use them already leaves out of the analysis certain areas of the world, which are also usually the most vulnerable. On the other hand, works analyzing the social perception of flood risk have also been increasing (e.g. Bodoque et al., 2016; Guardiola-Albert et al., 2020). I think it would have been interesting to have mentioned here, even if only briefly, the advances and gaps to be addressed with respect to the social perception of risk and whose advances could help to improve the characterization of vulnerability indicators related to the adaptive capacities of the population.

A: We agree that the use of google trends and twitter data could be used only in some specific countries. We modified the text to account for this.

"For instance, recent advancements have been made by applying geostatistical methods to psychosocial survey data (Guardiola□Albert et al., 2020). As an alternative, people's risk perception could be derived from widely available data sources, including, for instance, Google trends (e.g. Kam et al, 2019) and twitter statistics (Dyer and Kolic, 2020). Nevertheless, it should be noted that such approaches can be considered only where the use of social media and search engines are prevalent across the society." (lines 287-292).

- Line 294: Normally, variables related to population projections are already included among the social indicators of vulnerability indices. I agree that we should try to know how vulnerability will vary in the future, taking into account different scenarios. However, I believe that there is still a lack of knowledge to be able to define with some consistency the scenarios that should be used without their uncertainty invalidating the models themselves.

A: We agree with your remark. We modified the paragraph to include this perspective. The text now reads: "These could make use of, for instance, population growth projections or by employing tools such as qualitative futuring techniques (Hoffman et al., 2021). Nevertheless, it is important to notice that this can further increase the uncertainty of the vulnerability modelling outcomes. Still, it can serve as a guiding exercise on plausible futures. (lines 315-317).

- Lines 306-308: One of the main reasons why the results of vulnerability indices are not validated is because the necessary data are not always available. As mentioned in the article, validation is usually carried out using a secondary database on the number of deaths or the value of economic damages, among others, referring to a specific event or year; however, updated and accurate data on the consequences of floods are rarely available, making it difficult to validate the results.

A: Thanks for the comment. We made a slight modification to the text to clarify this: "In this regard Fekete (2009) points out the difficulty of finding empirical

evidence about vulnerability because vulnerability is multidimensional and not directly observable." (lines 329-331).

- 3: It is difficult to distinguish which bar corresponds to each category because the colors used are very similar. I would have chosen a differentiated color palette and not a range within the same color, such as the one used in blue.

A: Thanks for the observation. We changed the colors on Fig. 3.

- Line 162: The word 'in' is repeated. Delete one of the two words, please.

A: Thanks for the observation. We corrected this (line 182).

- Line 187: The reference does not have the correct format.

A: Thanks for the observation. We corrected this (line 198).

- Line 188: Delete the parenthesis after 'e.g.' and before the references.

A: Thanks for the observation. We corrected this (line 199).

- Line 207: Delete the parentheses before the references.

A: Thanks for the observation. We corrected this (line 218).

- Line 211: The acronym AHP has not been used before, so it should be defined for the first time here.

A: Thanks for the observation. We defined the full name "analytical hierarch process (AHP)" (lines 222-223).

- Line 215: The acronym ANP should be defined in this line for the first time.

A: Thanks for the observation. We defined the full name "analytical network process (ANP)" (line 226).

- Line 246: The reference should begin with a capital letter after the stop.

A: Thanks for the observation. We corrected this (line 256).

- Lines 270-271: The sentence 'Therefore, when dealing [...] flood experience (Beringer and Kaewsuk, 2018)' appears to be unfinished.

A: Thanks for the observation. We completely this sentence: "when dealing with flood vulnerability, other relevant indicators such as risk perception (Carlier et al., 2018), past flood experience (Beringer and Kaewsuk, 2018) are important. However, data on these are often not readily available, thus requiring local research, which demands time, financial resources and a multidisciplinary team." (lines 283-286).

- Line 293: It is necessary to define FRR, as it appears here for the first time in the text.

A: Thanks for the observation. We replaced FRR for "flood risk reduction" (line 314).