

We are very grateful to the reviewer for the helpful comments on our manuscript. We have addressed all the comments made by the reviewer. To facilitate the review, we have modified the manuscript highlighting in yellow the changes carried out. We have taken advantage of this new opportunity to improve text, figures and tables as the reviewer has requested. In this regard, the concept of both vulnerability and all its components (i.e. sensitivity, exposure and resilience) have been clarified. As the reviewer recommended, we have created a new subsection under the section 2 (i.e. "2.2.2 Database generation"). Moreover, we have modified Figure 3 by adding the description of the variables in order to increase readers' friendliness as the reviewer suggested. To facilitate the understanding of the results, we have added a new column to Table 2, indicating the vulnerability component to which each vulnerability factor belongs. Conclusions have been amended to express clearer how the methodology proposed here constitutes an improvement on the state of the art and the extent to which the results may be included in flood risk management plans.

### **Reply to Anonymous Referee #1 comments and changes made**

I have read the paper with great interest and the main objective addressed by the manuscript is framed appropriately to the scope of the journal, but there is some confusion regarding to the term vulnerability. Therefore, I think that the paper needs some revisions and I recommend to accept it only after these revisions.

#### Specific comments

##### Introduction.

- In general, vulnerability in the context of natural hazards is a broad term, which covers different dimensions from physical to social approaches. In this line, it is important from the authors to give a clear framework of the vulnerability concept used in this study. Try to explain better or make more explicit the links what do you deal with. For example, it is not clear to me what the authors understand as vulnerability, integrated vulnerability and the components influencing vulnerability. In this part and in order to avoid confusion, I would suggest the authors to clearly indicate what they define as vulnerability in the context of the existing frameworks as well as a clear definition of the terms exposure, sensitivity and resilience.

In spite of some confusion around the use of the vulnerability terminology, there is a certain consensus about what issues should be assessed to its characterization. The vulnerability analysis carried out in this paper has followed a hybrid approach (Eakin and Luers, 2006) between risk-hazard approaches, which considers that vulnerability depends on the biophysical risk factors and the potential loss of a particular exposed population (e.g. the hazards-of-place model of vulnerability; Cutter, 1996); and political economy/political ecology approaches, which emphasize the political, cultural and socioeconomic factors that explain the differential exposure, impacts and capacities to recover from an impact (e.g. the pressure and release model; Blaikie et al., 1994). Taking into account the key parameters for the vulnerability research that highlight the above-mentioned approaches, we understand that vulnerability depends on the social system's exposure and sensitivity to stress (exposure and sensitivity components of our Integrated Social Vulnerability Index, ISVI) as well as its capacity to absorb or cope with the effects of these stressors (resilience component of our ISVI) (Eakin and Luers, 2006; Adger, 2006; Birkmann et al., 2013). In this context, we define 'exposure' as the people and assets susceptible to be harmed; 'sensitivity' as the level to which people and assets can be damaged; and 'resilience' as the ability to absorb, cope with and recover from the effects of a disaster. Furthermore, the social dimension of vulnerability (i.e. social vulnerability) has been traditionally estimated through the construction of indexes, which are composed of several vulnerability factors (usually derived from a factor analysis or principal component analysis)(Cutter et al., 2003). Each vulnerability factor is in turn composed of several variables (variables considered as a means of explaining social vulnerability, such as age, gender, unemployment...). Traditional social vulnerability analysis usually shows the results for each vulnerability factor and for the total social vulnerability (i.e. the combination of the above vulnerability factors), but they do not analyze the results by component. We have constructed a

social vulnerability index using an integrating approach (i.e. integrating elements from risk-hazard and political economy/political ecology approaches)(Eakin and Luers, 2006), which has been called Integrated Social Vulnerability Index (ISVI). This enables us to find out the involvement of each vulnerability component (i.e. sensitivity, exposure and resilience) to the total vulnerability and their interactions (Frazier et al., 2014), which also facilitates the incorporation of the analysis results into the flood risk management plans, particularly at regional scales.

In view of the above, and in agreement with the reviewer, we have included in the text the theoretical concepts of:

- vulnerability assessment (page 2, lines 15-17).

"Many efforts were put in flood hazard analysis in past, but vulnerability assessment (**i.e. the analysis of the characteristics of a person or group and their situation that influence their capacity to anticipate, cope with, resist and recover from the impact of a natural hazard**) is still one of the biggest constraints in flood risk assessment to date".

- sensitivity, exposure and resilience, in which the integrated social vulnerability index is based on (page 3, lines 2-3).

"Less attention has been paid to integrated analysis of vulnerability components, which considers the differential influence of exposure (**i.e. people and assets susceptible to be harmed**), sensitivity (**i.e. the level to which people and assets can be damaged**) and resilience (**i.e. the ability to absorb, cope with and recover from the effects of a disaster**) on total vulnerability".

- integrated vulnerability (page 3, lines 16-18).

"This paper aims to calculate an integrated social vulnerability index (ISVI) to flash floods, **which considers separately the vulnerability components (i.e. exposure, sensitivity and resilience), analyzing the involvement of each of them in total vulnerability**".

Materials and Methods.

- The study area is well described. The methodological outline is well described and the method sounds scientifically correct (I am not an expert on statistics). I would suggest the authors to make figure 2 more simple by reducing some information that is presented on the text.

We have simplified the Figure 2 in order to make it clearer and easier to understand. Moreover, we have done a terminological change from 'municipalities' to 'urban areas', since municipalities is usually used to refer to administrative boundaries or local administration (i.e. the council). Thus, we have used the term 'urban areas' when we talk about the areas prone to flash flooding and 'municipalities' when we refer to the town halls. Moreover, we have added the green color in order to show clearer the final results.

- Moreover, it is not entire clear to me, why the authors used a low probability scenario and not scenarios with medium or high probability.

We have used the scenario of low or exceptional probability (500-year flood) because it is the flood hazard zone that is the most comprehensive representation of urban areas that could be affected by flash floods at regional scale, according to the European Flood Directive.

- In page 5/line 6, I would recommend the authors to create a new subchapter with the database generation.

Done (page 6, line 8). Thank you for the recommendation.

### "2.2.2 Database generation"

- Moreover, I would suggest them to describe a bit more the data used and to give some more information about the surveys done (i.e. telephone calls and/or personal research).

We have extended the 'Database generation' subsection including more information about the variables included in the integrated social vulnerability analysis and how they were gathered (page 6, lines 12-14).

"However, the other 29 variables were requested from certain public organizations or councils by means of telephone calls, **asking for information directly from the person in charge** (e.g., dependency, development and infrastructures...) or generated through personal research **estimating the variables through other non-specific sources of information** (e.g., collective vulnerability, healthcare services...)"

- Additionally, on the construction of the Integrated Social Vulnerability Index (part 2.2.4), I would recommend the authors to describe a bit more the idea behind the equation's modification from the original one presented by Frazier et al. (2014).

Frazier et al. (2014) also used an integrated approach in the development of their Spatially Explicit Resilience-Vulnerability (SERV) model. However, the equations used in our ISVI represent an adaptation from the ones used in the above-mentioned article, since we have adapted the equations to our terminology (i.e. changing the term 'adaptive capacity' to 'resilience') and we have used a different method to weigh the vulnerability factors (i.e. using tolerance statistic instead of the percentage of explained variance). Therefore, we have replaced in the text the term 'modified' by 'adapted' (page 9, lines 8 and 11) and we have added a clarification in the text about this adaptation (page 9, lines 15-17).

**"The index construction method implemented coincides with the same method developed by Frazier et al. (2014), although the tolerance statistic was used here as a weighting method".**

Results.

- In general, I would suggest the authors to describe only their results to this part and to remove some parts describing methods (i.e. page 11/ lines 1-5 or page 12/lines 5-6) on the methodology part as well as some parts discussing their results (i.e. page 16/lines 11-13) to the discussion part.

We have removed the text related to the methodology and the discussion from the results section.

Moreover, we have moved the text of page 12 (lines 5-6) to the bottom of Figure 4 since it was describing this picture (page 13, bottom of Figure 4).

**"Figure 4: Factor scores for identified vulnerability factors. For exposure and sensitivity factors, very high categories correspond to red colors while for resilience factors, very high categories correspond to blue colors".**

- On figure 3, I would suggest to add the description of the variables to increase reader's friendliness.

Figure 3 have been modified including the description of the variables. Thank you for the suggestion.

- At the end, the conclusions presented are too general and do not reflect what exactly shown in this study. Conclusions based on the findings of the analysis presented would be more effective.

The conclusions have been reworded trying to make them more specific. They have been amended in order to express clearer how the methodology proposed here constitutes an improvement on the state of the art and the extent to which the results may be included in flood risk management plans and therefore improve flood risk management, which is the main objective of this social vulnerability analysis.

**"A comprehensive characterization of social vulnerability is critical for an integrated FRM. The implementation of an HSA helps to overcome PCA sample size limitation, meaning an alternative methodology to the usually used to construct an ISVI in areas where available data is limited. The results show the high spatial heterogeneity of the social vulnerability within the study region and the high variability in the ISVI scores regarding the interactions between vulnerability components, which 5 makes an integrated analysis more important. The identification of vulnerability patterns through**

the LCCA gives the sources of vulnerability in each urban area, which simplifies the spatial heterogeneity analysis of the social vulnerability and enables to know what aspects need to be improved in order to decrease sensitivity and exposure (e.g. urban areas that compose cluster 2 are mainly made up of elderly people that usually need an external aid to reach shelter, so they should develop very effective evacuation plans in order to coordinate the different competent authorities) and what aspects need to be reinforced to increase resilience (e.g. a high percentage of dwellings of urban areas that compose cluster 2 are in poor condition, so they could reverse this situation providing financial aid or promoting a tax cut of dwellings in good condition in order to involve population). Thus, a better integration of the ISVI results into FRM plans and policies is made possible enabling to propose specific strategies of vulnerability reduction, increasing their efficiency".

#### **CITED REFERENCES:**

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