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Natural Hazards and Earth System Sciences
Discussions

Interactive comment on "Construction of an Integrated Social Vulnerability Index in urban areas prone to flash flooding" *by* Estefania Aroca-Jimenez et al.

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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 and figures as the reviewer has requested. In this regard, the inclusion of exposure in the Integrated Social Vulnerability Index has been clarified, adding a new reference for this purpose. We have simplified the Figure 2 in order to improve its understanding. Moreover, we have explained better the concept of 'optimum number of clusters' at the results section, extending the information with regard to the BIC and the CAIC statistics. We have also modified the

text of the section 4.3 ('Policy implications'), giving some practical examples of specific mitigation measures that can be suggested for each cluster of urban areas. Finally, 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, as both reviewers have recommended.

Reply to Anonymous Referee #2 comments and changes made

First of all, I very much enjoyed reading the manuscript. I have, however, a few comments to improve the manuscript. Please find them below.

Comment 1 - Abstract, line 16: 'it has not yet provided'. Please rephrase this a bit, the sentence is unclear.

Reply 1 - We have rephrased the sentence. As the reviewer pointed out, the sentence was badly phrased (page 1, lines 16-18).

Change 1 - "As far as we know, a methodological approach to construct the ISVI in urban areas of Castilla y León (northern central Spain, 94,223 km2, 2,478,376 inhabitants) prone to flash flooding has not yet been provided".

Comment 2 - some additional explanation is required on the inclusion of exposure in the social vulnerability index. In the traditional risk framework, exposure and vulnerability are two different components of the framework. As many researchers from the risk field read this journal, it should be specifically emphasized that including exposure is common practice in the social vulnerability field, even though this may contradict to the definition of risk and vulnerability which is more commonly used in the disaster risk community. This is important for the interpretation of the results.

Reply 2 - As the reviewer point out, exposure is commonly included in the social vulnerability analysis. Although exposure and vulnerability are two different components of risk, currently exposure is included in the social vulnerability assessments in order

to provide a holistic characterization of vulnerability, since it is not possible to talk about potential for loss (i.e. vulnerability) in the absence of exposure (Frazier et al., 2014). In the same way, resilience is also included in social vulnerability analysis, since the potential for loss also depends on the ability to absorb, cope with and recover from the effects of a disaster. Thus, a comprehensive social vulnerability assessment should include 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). Therefore, we have explained that the inclusion of exposure in the social vulnerability analysis is a common practice (page 3, lines 7-9). We have also included a new reference in order to strength this idea.

Change 2 - "Although exposure and vulnerability are assumed to be two different concepts in the traditional risk framework, currently the inclusion of exposure as a factor to be considered is a common practice to assess social vulnerability".

Comment 3 - I have a few questions and a suggestion regarding Figure 2.

Change 3 - 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.

Comment 3.1 - why is there an arrow going from Flash flood low probability municipalities to socioeconomic variables? Because the flash flood box is blue, it now seems like a hazard variable is added to the socioeconomic variables. This is, however, not the case (and should not be the case either).

Reply 3.1 - We wanted to show with this arrow that socio-economic variables had only been gathered to those urban areas that met the defined requirements, which were

then named as 'Flash flood low probability municipalities'. In order to facilitate the understanding of this part of the Figure 2, we have modified the color of this box from a blue plain to a gradient blue-beige color, indicating that the 'Flash flood low probability municipalities' box is the beginning of the second part of the figure (beige boxes).

Comment 3.2 - why are sensitivity and exposure 'clustered' and is resilience not in this cluster?

Reply 3.2 - All vulnerability components (exposure, sensitivity and resilience) were taken into account in the Latent Class Cluster Analysis (LCCA), using as input data the factor scores of the urban areas of interest. The minus sign which is placed on the arrow that goes from the box 'Factor scores' to 'Resilience' box indicates the sign of the component when the Integrated Social Vulnerability Index (ISVI) was calculated, and not that Resilience was not considered in the LCCA. Traditionally, factors that express sensitivity or exposure are considered as positive values in the ISVI (see the plus sign that is placed on the arrow that go from the box 'Factor scores' to 'Sensitivity' and 'Exposure' boxes); while factors that state resilience are considered as negative values, as has been done here.

Comment 3.3 - Perhaps add a third color that specifies the (final) results. This would make it more clear why some arrows exist in the framework (for instance the arrow from factor scores to clusters of municipalities).

Change 3.3 - Done. Thank you for the recommendation.

Comment 4 - Section 2.2.2: I do not fully understand the use of the Euclidian distance method. If I do understand it correctly, the sum of the differences between variable values is considered to be the distance? So distance is not spatial? I think it would be good to explain this a bit more clearly, as some parts of the paper are spatial (the clusters of municipalities for instance). This causes (at least for me) some confusion.

Reply 4 - We have changed the term 'distance' by 'similarity' in the text in order to clarify

that we were not talking about spatial distance (page 8, line 9). From a statistical point of view, distance measures are a type of similarity measure, so it is correct to use the term 'similarity'. We have used the Euclidean distance to evaluate how similar to each other the variables were, as is explained by Euclidean distance definition (page 8, lines 9-10). The greater the distance among variables are, the less similar the variables are. Hierarchical Segmentation Analysis (HSA) groups variables according to their similarity rather than the distance.

Change 4 - "Once the variables were standardized (Cutter et al., 2003), the squared Euclidean distance was used as a similarity measure, i.e., the square of the square root of the sum of the differences between variable values".

Comment 5 - Captions of Figure 4 and Figure 5 could be a bit longer. Figure + figure caption should be self-explanatory.

Reply 5 - We understand the comment about captions of Figure 4 and Figure 5, but we decided to shorten them in order to have a more balanced length of the text of this section.

Comment 6 - Figure 3 is perhaps not required, as it shows roughly the same as table 2? Perhaps move to appendix, as table 2 shows everything we would like to know (the variable clusters and the factor names)

Reply 6 - Figure 3 and Table 2 do not show the same information. Figure 3 corresponds to HSA output while Table 2 corresponds to the Factor Analysis (FA) output, which includes factor loadings that are necessary to construct the ISVI. HSA helps to overcome the Principal Components Analysis (PCA) sample size limitations, so we think that including the HSA output (i.e. the dendrogram) into the results section of this paper is an interesting approach.

Comment 7 - Section 3.2: I am a bit puzzled with the notion of 'optimum number of clusters'. What does an optimum amount of clusters mean? Ok the statistics say so,

but as a practitioner, what would it matter if you would have four clusters? How would this change the interpretation of the results?

Reply 7 - BIC and CAIC are statistics that enable to establish a number of clusters, which can be used in flood management. We used the BIC and the CAIC criteria in order to select the more parsimonious number of clusters (i.e. the number of clusters that provides as much information as possible taking into account the number of parameters to estimate). The more information is explained by the model, the greater the number of estimated parameters will be. The above is shown in Table 3 (Page 15). The minimum values of the BIC and the CAIC statistics are reached with a model of 3 clusters, and their values increase again in the estimations that consider four and five clusters. This means that the number of parameters to estimate by the model (see Table 3, 'Number of parameters' column) are too high in comparison to the obtained increase of explained information ('Log-likelihood(LL)' column). From a practical point of view, the above means that an increase in the number of clusters from 3 to 4 or 5 would split a fairly homogeneous cluster of urban areas into several subgroups which would not be very different from each other. Therefore, a greater level of disaggregation would not help to improve the implementation of different flood risk mitigation measures for each cluster of urban areas. Therefore, we have extended the information about the BIC and the CAIC criteria in the text (page 15, lines 2-3).

Change 7 - "The BIC and CAIC statistics were used in order to select the more parsimonious number of clusters (i.e. the number that provides as much information as possible taking into account the number of parameters to estimate)".

Comment 8 - Section 4.1: I would suggest to move parts of this to the method section. Most parts of this section are regarding the interpretation of the results. It is better to make this clear before the results section, instead of afterwards. A discussion after the results, weakens, in my opinion, the results.

Reply 8 - We have removed some parts of the text from section 4.1 instead of moving

the text because the text of the methodology section is already very long and it contains all the ideas that the authors considered important.

Comment 9 - Section 4.3: I suppose the clustering of municipalities is interesting from a policy making perspective. It would be good to link the clustering to this section. How can it improve policy making if we can identify similar municipalities?

Reply 9 - We have extended the text of the 'policy implications' section trying to emphasize the practical utility from a policy making perspective of the Latent Class Cluster Analysis (LCCA). For this purpose, we have included practical examples of specific mitigation measures that could be proposed for each cluster of urban areas identified by the LCCA (page 20, lines 16-26).

Change 9 - "The identification of social vulnerability patterns help to identify the most suitable mitigation measures for each cluster of urban areas identified by LCCA, in addition to prioritize the available resources. For instance, mitigation measures for those urban areas included in cluster 1 should be targeted towards improving the physical resilience (e.g. raising the first-floor elevation above ground level) and helping population financially with the implementation of mitigation measures (e.g. providing financial aid to those dwellings located at flood-prone areas). On the other hand, the population that live in those urban areas included in cluster 2 are highly dependent on external assistance due to high rates of ageing population, so emergency services should have adequately characterized the different evacuation routes (e.g. promoting the design of evacuation routes and the construction of shelters near those urban areas). Finally, mitigation measures for urban areas included in cluster 3 should be aimed at the collective facilities (e.g. practicing of flood emergency drills) and to encourage the implementation of individual mitigation strategies (e.g. through a financial incentive system, such as the repayment of part of the money spent at municipal taxes)".

Comment 10 - Please make the conclusions a bit more specific for this paper. What can we really learn from this paper, especially from a policy making perspective. What

does this paper add, besides being the first study on flash floods? A few lines on the conclusions for the study region (specific patterns identified) would be interesting as well.

Reply 10 - 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 (page 21, lines 8-16).

Change 10 - 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 make 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 and what aspects need to be reinforced to increase resilience. 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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Frazier, T. G., Thompson, C. M., and Dezzani, R. J.: A framework for the development

of the SERV model: A Spatially Explicit Resilience-Vulnerability model, Applied Geography, 51, 158-172, 10.1016/j.apgeog.2014.04.004, 2014.

Please also note the supplement to this comment:
http://www.nat-hazards-earth-syst-sci-discuss.net/nhess-2016-408/nhess-2016-408-AC6-supplement.pdf

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