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Hydrology and Earth System Sciences
Discussions

Interactive comment on "Participatory flood vulnerability assessment: a multi-criteria approach" *by* Mariana Madruga de Brito et al.

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Dear Referee,

Thanks for reviewing our manuscript. Your comments and observations are very informative and constructive. The manuscript will be revised according to the provided suggestions, which will help to improve the paper before final submission. Please find our response to each one of your comments and questions below.

1) "This well-written paper outlines a process for employing a multi-attribute index assessing flood vulnerability. Of particular concern is the participatory approach to constructing this index, allowing for several stakeholders and ex-

perts to take part in the construction, essentially when weighting the attributes in terms of their relative importance."

Thank you for the careful reading and the positive appreciation of our manuscript.

2) "The weighting is done using the AHP and ANP approaches, which are popular approaches especially in works employing decision analysis, but sometimes questioned within the decision analysis community itself. Having that said, I wish that the authors addressed other weight elicitation methods within the process outlined in this paper, for an overview see, e.g., the paper M. Riabacke, M. Danielson, L. Ekenberg, "State-of-the-Art Prescriptive Criteria Weight Elicitation," Advances in Decision Sciences, Volume 2012 (2012), Article ID 276584.

For instance, the AHP might restrict the index to fewer attributes than desired due to the requirement for many pairwise comparisons which is avoided in other rank based approaches such as rank-ordered centroid weights or cardinal ranking approaches.

***H. K. Alfares, S. O. Duffuaa, "Assigning cardinal weights in multi-criteria decision making based on ordinal ranking," Journal of Multi-Criteria Decision Analysis, Volume 15, Issue 5-6 , 2008.**

***M. Danielson, L. Ekenberg, "The CAR Method for Using Preference Strength in Multi-criteria Decision Making," Group Decision and Negotiation, Volume 25, Issue 4, 2016.**

Thanks for raising this very important issue. As mentioned by several authors, criteria weighting is one of the most critical and sensitive steps in MCDM (e.g. Edjossan-Sossou et al., 2014; Meyer et al., 2007). Hence, careful attention should be paid to this step when developing vulnerability indexes. In this study, other weighting methods such as the DEMATEL (decision-making trial and evaluation laboratory) and WINGS (weighted influence non-linear gauge system) were tested with 4 researchers in a previous stage of the research. Nevertheless, they both proved to be too demanding for the respondents.

Therefore, we have opted to use the AHP and ANP methods, which are widely recognized for being easy to use and understand by stakeholders (Dang et al., 2011; Yang et al., 2013). As mentioned by the Referee, AHP is one of the most common MCDM tools in GIS applications (Malczewski and Rinner, 2015) as well as in flood-related studies (de Brito and Evers, 2016). Thus, some of the participants were already familiar with the pairwise comparison approach, making the use of AHP and ANP appealing. The ANP method was chosen because it allows considering the interconnectedness of the input criteria, which was critical to the proposed framework. Indeed, the vulnerability criteria are not independent as multiple interactions between them exist. To overcome this problem, MCDM methods which enable considering inner and outer dependencies between criteria are necessary.

We completely agree with the Referee that a limitation of AHP and ANP is that the number of criteria has to be small. If a large number of criteria is used the procedure becomes operationally too complex and cognitively demanding due to the larger number of pairwise comparisons needed. This was briefly mentioned in the manuscript (see Page 19, lines 17-19). Despite this drawback, the feedback questionnaire showed that most participants are willing to apply the methodology in the future. We will expand the discussion of this limitation in Section 5.3 "Limitations and future research".

An advantage of AHP and ANP when compared to other MCDM methods cited by Riabacke et al. (2012), is that they allow deriving a consistency ratio (CR) of the participants response. The CR offers a useful guide to the validity of the surveyed individual's viewpoint (Mardle et al., 2004). It also allows improving the coherence among redundant judgments (Rahman et al., 2009).

We were not familiar with the SMART, SMARTER, CAR and SWING tools when we conducted the weighting elicitation workshops. To the best of our knowledge, these methods are not commonly applied in the flood risk management community. Indeed, in a systematic literature review of 128 papers conducted in a preliminary step of this study (de Brito and Evers, 2016), only one paper used the SWING approach (Meyer et al., 2009). However, these tools seem to be appropriate for the problem at hand and we agree with the Referee that it would be interesting to use them in future applications.

As mentioned in the paper suggested by the Referee, the centroid weights method provide almost the same accuracy than AHP while requiring much less input and mental effort from decision makers (Alfares and Duffuaa, 2008). Also, in the experiment conducted by Danielson and Ekenberg (2016), the authors found out that CAR and SMART require less amount of time and effort, and are perceived as more transparent than AHP. Therefore, the possibility of applying these methods to weight vulnerability criteria will be added to the discussion section of our manuscript in order to guide future applications.

3) "The text on value functions is a bit hard to penetrate how the value functions were constructed in the participatory process. The selection of only two membership classes for instance (low vulnerability, high vulnerability), was that made by the focus group or designed by the authors on beforehand and why is this sufficient for the model presented?"

We did not use classes to build the value functions. Our main intention when using value functions was to avoid defining crisp boundaries. Hence, the data was standardized using a continuous space, ranging from 0 (no vulnerability) to 1 (full vulnerability). The elicitation of the value functions was done with the support of the IDRISI® GIS software.

Due to the complexity of the task, the participation in the focus group was limited to 5 experts. The original criteria maps were printed to provide a visual representation of the criteria spatial distribution as well as their minimum and maximum values. In a first step, the participants had to choose the type of the function used to standardize each criterion. They could be: (1) sigmoidal or s-shaped; (2) j-shaped; (3) linear; or (4) user-defined. The mathematical equations used to build these functions and their basic assumptions are described by Smith et al. (2008).

After selecting the type of the function, the participants had to define if the function was increasing, decreasing or if it was symmetric (Figure 1 below). For example, a decreasing value function was used to standardize the criterion “monthly per capita income” as a higher income leads to a reduced vulnerability. On the other hand, an increasing function was used to standardize the criteria “density of persons under 12 years”, since the higher the concentration of children, the more vulnerable the area is.

Finally, the experts had to determine 4 points of the function:

a = membership rises above 0
b = membership becomes 1 (full vulnerability)
c = membership falls below 1
d = membership becomes 0 (no vulnerability)

For example, in standardizing the monthly income criteria, the participants chose to use a sigmoidal decreasing function (Figure 2 below). The control points a, b and c where equal to 510 R$, which was the minimum wage in 2010, when the census data was collected. Hence, the houses with an income of less than 510 R$ were assigned the highest vulnerability scores. The control point d, was set to 2100 R$, which corresponds to the living wage in 2010. In Brazil, the living wage is the minimum income necessary for a worker to meet their basic needs such as shelter, food, transport, health care, clothing, and recreation. We will revise the text and add a detailed description of the procedure adopted to define the value functions.

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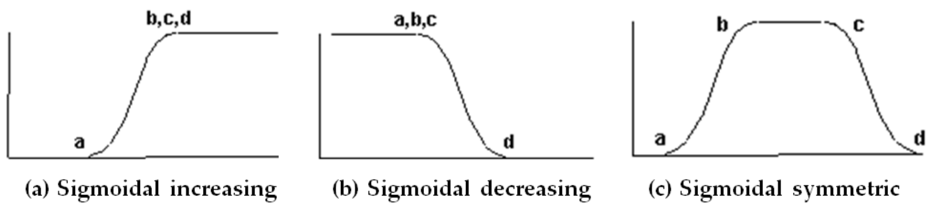

Fig. 1. Types of sigmoidal functions and control points. Source: (Eastman, 2003)

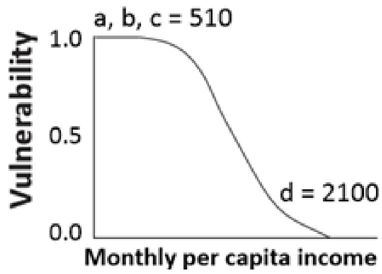

Fig. 2. Value function used to standardize the monthly per capita income