MS No.: nhess-2021-8

Dear Editor,

Please find us kind of astonished to receive minor revisions on our work for the fourth time. We would like stress the answers we already brought:
1) 19 Jan 2021 (Comments to the Editor – Minor revisions);
2) 01 May 2021(Referees #1 and #2 – Major revisions);
3) 20 Aug 2021(Referees #1 and #3 – Accepted as it, and Minor revisions).

However, as we are convinced that our work contributes to bring a paradigm shift, considering the integrated socio-spatial vulnerability, a new perspective to assess the vulnerability to cyclonic coastal flooding, and provides a framework for future research on this topic, we respond to these new comments with devotion, precision and objectivity, as it has been always the case.

In the following, we address you point-by-point all the answers and we will modify the manuscript accordingly.

(a) How do you define coastal zone in Bangladesh? According to the policy document of Bangladesh, there are 19 coastal districts. This should be consistent.

This remark is quite relevant, as the coastal zone can be defined according to several criteria. For example, Mullick et al., 2019 chose the same districts to conduct their study on coastal vulnerability. But to be more specific, we suggest adding this text, section 5 line 416:
“To identify places that are highly vulnerable to cyclonic flooding hazard, we focus on 16 coastal districts, the district being the spatial unit of reference (Fig. 1a). The 16 costal districts were selected following the classification given by the Program Development Office for Integrated Coastal Zone Management Plan (PDO-ICZMP, Uddin & Kaudstaal, 2003) which considered 12 “exposed” districts to the sea and/or lower estuaries (i.e Khulna, Satkhira, Barguna, Cox's Bazar, Bagerhat , Patuakhali, Pirojpur, Chittagong, Noakhali, Bhola, Lakshmipur and Feni). We added also to this selection 3 districts located on the mouth area of the GBM delta and cited in the literature review: Chandpur, Shariatpur and Barisal (Fig. 1a, see Appendix B.b). Moreover, the district of Jhalokati bounded by Barisal, Pirojpur and Barguna districts, is added to our selection because it is cited in the literature review in 5 studies.”

Uddin, A. M. K., & Kaudstaal, R. (2003). Delineation of the coastal zone. Program Development Office for Integrated Coastal Zone Management Plant (PDO-ICZMP), Dhaka, 1–42.

(b) The statistical database is available at sub-district (Upazila) or Union level. Why you used district level data, even data is available at lower administrative level. I would suggest to conduct the study at lower administrative level (i.e., Upazila). This will add more value for local decision makers.

First and foremost, we agree with the editor about the need to work on upazila and union levels. It is exactly the focus we adopt in a further paper currently in preparation. Nonetheless,

working at the smaller administrative level would be a thorn in the side in the context of this study.

Using the district scale is related to the multifold aims of our research. First, one of the objectives was the spatial identification of hotspots of vulnerability to cyclonic flooding, intending both to identify the spatial variability linked to cyclonic flooding facing the district; and districts where the combined effects of multiple social, economic and environmental stressors are most prevalent regarding the cyclonic flooding.

Secondly, by using this territorial delimitation, it enables us **to zoom out** the research fieldworks made from 2007 on, in order to show which zones have been under the scope of science and other very exposed and vulnerable zones, almost forgotten from studies. While most of the analysed studies worked on local places, they did not give a whole picture to the reader about the work made in coastal Bangladesh. We detailed all the analysed sites studied by district, since an article could study many villages or upazila in the same district. The distribution of the studies on the map shows that two main districts on the west coast were over-studied (Shatkhira and Khulna) compared to the need of studying now the most vulnerable districts, situated in the mouth of the Delta. Our research consequently shows the gap between the existing scientific research and the geographical zones that should be prioritized by academics for further studies because of their socio-spatial vulnerability characteristics.

Moreover, the interest to study at the district scale is linked to the alert and the cyclone **warnings dissemination system in Bangladesh**. For instance, the community leaders in rural areas (the *samaj*) fill a special role in coastal districts, at informing the population about imminent hazards, via megaphones and by house-to-house contacts (Paul, 2009). They may also perform other duties such as maintaining cyclone shelters and assisting in evacuation procedures (Kulatunga et al., 2014), key-points among other factors of our defined vulnerability. In the post-disaster period, the *samaj* also contribute toward food, financial aid and other material support (Alam and Collins, 2010). It is therefore the scale to encompass key actors intervening during both the pre-disaster and the post-disaster phases of the cyclonic hazard.

Finally, our methodology was developed in order to support district assessments and provide suitable information for identifying districts where vulnerability to cyclonic flooding could be relatively high and for questioning the preparation of strategies for the elaboration of mitigation and adaptation policies in these hotspots.

(c) When you described the results, I do not find any validation. At least you should support your results through secondary literature. Justification why certain area is more vulnerable than other?

This point has been discussed previously as a response to a comment raised by the Referee#1 (see our reply R1.11). The definition of vulnerability varies greatly from one study to another, making a comparison difficult between several studies. However, the one made by Quader et al. (2017) is the most relevant to us in order to perform this exercise. Based on that R1.11 comment, we have already modified our discussion as follows lines 562-582 : " […] comparing

vulnerability studies of coastal districts exposed to cyclonic flooding risk remains very difficult because the definition of the vulnerability concept varies greatly from one study to another. Quader et al. (2017) is certainly the most recent study offering a definition and an assessment of vulnerability, as well as the most relevant to our study. The results corroborate that the districts in the mouth of the Meghna (central coast) up to Chandpur and Shariatpur districts, as well as the Bagerhat and Cox's Bazar districts are highly vulnerable. The only notable difference is situated in Shatkhira district, which according to our study is vulnerable, while according to Quader et al. (2017) is very low vulnerable. In detail, the different dimensions of vulnerability are not described in the same way by the two studies. For example, accessibility to electricity is used to define demographic and basic facilities vulnerability in Quader et al. study, while it is used to define the vulnerability of infrastructure and housing in our SSVI. Similarly, disability is sometimes used to define household vulnerability (SSVI), and sometimes considered as a separate dimension of vulnerability (Quader et al., 2017). Moreover, we used a robust probabilistic cyclonic flood hazard map based on a dataset of 3600 statistically and physically consistent synthetic cyclone events (Emanuel et al., 2006; Khan et al. 2019). While Quader et al. (2017) used a low level of confidence cyclone hazard density interpolated map based on historical cyclone tracks (~160 events in 1877-2015). Although the level of detail provided by this union-wide study is significant, the closeness of the results is meaningful. However, social vulnerability is defined from 141 variables and a consistent workflow with several statistical methods. On the contrary, in our study, we have devoted a strong attention to the theoretical links between indicators and underlying vulnerability to cyclonic flooding, by conducting a strict literature review. Therefore, SSVI is computed from only 17 variables and a simple computation of index appears easier to understand its construction and to replicate by decision makers."

Also, I would indicate key recommendations how vulnerability be reduced.

Providing "key recommendations to reduced vulnerability" is valuable and interesting, but it is regrettably out of the scope of our study.

(d) The most critical one: I do not find logical justification of choosing the approach: if you do not find any available studies on particular approach or indicators, you have not considered them. Then, what is the novelty of the study? The approach you considered might be applicable for review paper. For ensuring novelty, it should be other way around.

We are not sure to correctly grasp the Editor's comment questioning upon *the approach*. As previously explained in the manuscript, the most common vulnerability indexes are based on inductive and deductive approaches. Inductive approaches use large sets of variables to build statistical models (e.g principal components analysis), that explain observed vulnerability through some indicating variables. Although a large number of variables may be useful for descriptive purposes, including non-influential variables in the index aggregation may decrease both explanatory power and user level of understanding. Deductive models can contain a few dozen variables, or less, which are normalized and aggregated to index, which could be separated into groups sharing the same underlying vulnerability dimension (e.g Fig2 : socioeconomic, household composition and disability...). This approach is the most common structure applied to vulnerability indices. Deductive approach, based on a data-driven mindset from expert knowledge (literature review) and parsimony, helps to identify and trace underlying

themes running through the data, opposite to inductive approach where the statistical models obfuscate underlying data. We consider that the literature review is a rich source to understand the main causes, translated as indicators of vulnerability, their relative importance and interactions.

It is important to keep in mind here that our work is not limited to the definition of a vulnerability index to cyclonic flooding but provides also a framework for future research on this topic based on:

- its entry by the territory seems more useful to us in order to help decision makers in their decision making and their strategic orientations in risk management,
- a global and deductive approach was given to the definition of vulnerability (and not only for each of its dimensions),
- a robust probabilistic cyclonic flood hazard map was made, based on a dataset of 3600 statistically and physically consistent synthetic cyclone events.
- and finally, the definition of vulnerability alone was elaborated, without the adaptive capacities, but including exposure.

This paper presents a strong scientific and conceptual contribution, providing a sound methodological design with a simple computation of index easier to understand and to replicate by decision makers. We are convinced that our work addresses a topic of significant community interest. This interest of the community is already marked by the number of consultations of the preprint (nhess metrics: 640 views since February 2021).
Therefore, it appears necessary to publish the article fast enough to offer those new findings to interested searchers, policy makers and IOs-NGOs. And by offering a conceptual bridge to and in between both natural hazard and social sciences upon the notion of vulnerability, we strongly believe the article will feed the reasoning for scientists working on vulnerability to cyclones in Bangladesh.