

Interactive comment on “Linking local vulnerability assessments to climatic hazard losses for river basin management” by H.-C. Hung et al.

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Replies to the interactive comment on “Linking local vulnerability assessments to climatic hazard losses for river basin management” Anonymous Referee #2

1. The authors present a study that seeks to link typhoon losses within three river basins with vulnerability and coping capacity/adaptive capacity indicators. Particularly, the authors try to determine the statistical relationships between selected indicators and the observed losses using various regression methods. The presented study could provide interesting empirical/quantitative insights into the usefulness and the effects of, e.g., mitigation methods in the context of risk management, and might thus be considered for publication. There are, however, numerous substantial issues that need to

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be addressed by the authors, primarily in regard to the underlying conceptual framework. *Replies: The authors would like to sincerely appreciate the anonymous referee for providing us very valuable suggestions and comments. Our responses and relevant ways of dealing with each comment and suggestion are summarized as follows. Particularly, we will further clarify our article's conceptual framework and rewrite major portions of the manuscript to make it more understandable.

2. In the following, I am listing my main concerns. Despite those, the manuscript requires substantial language editing. I have just listed selected instances where language editing is required. *Replies: Many thanks for referee's suggestions. The authors will follow the referee's suggestions to improve the writing and the language problem in the manuscript. We will reorganize whole manuscript, including the word choice, grammar, sentence usage and structure. Finally, the revised manuscript will also have a thorough language editing for making the content intelligible and making the manuscript more suitable for publication.

3. The authors state their aim to "examine whether geographic localities characterized by high vulnerability experience significantly more damage [. . .]" (p. 3, l. 5). Significantly more damage in comparison to what? Please rephrase and clarify. *Replies: The sentence will be rephrased as: "This article aims to examine whether localities characterized by high vulnerability experience significantly higher damage than other areas owing to onset weather extreme events at the river basin level. . ." in the revised manuscript.

4. It is argued that several events hit the studied river basins. Maybe provide some more examples on additional events to put the study into a broader context, since just a singular event, i.e., Morakot, surely would not trigger exhaustive risk management but might be more treated like an outlier. *Replies: Indeed, this is a critical limitation in our study. In the study, we adopt a single case of Typhoon Morakot due to two key reasons. First, Typhoon Morakot was the most severely damaged typhoon to hit Taiwan in the past 50 years. This typhoon caused torrential rainfall that resulted in widespread

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flooding and thousands of landslides in the southern Taiwan areas. The damaged areas included all the three river basins discussed in the article, even though there were also several typhoons having hit southern Taiwan in the past years. This also leads to the following reasons for using only the Typhoon Morakot case. Second, except for Typhoon Morakot, most of the typhoons, which had hit southern Taiwan areas, are relatively scattered and smaller scales. This would cause difficulties in comparing disaster loss data between the various typhoons, while these typhoons are associated with different wind speeds, types of disaster impacts and various scales of precipitation and damaged areas. Particularly, most of these typhoons are deficient in the document of disaster losses and related database for supporting our analyses. Thus, our study focuses on developing a framework and methodology that allow us to link the local vulnerability assessments to climatic hazard losses at the river basin levels. We not only demonstrate the approach using Typhoon Morakot data as our initial step, but also recognize the potential of the application of our approach to other typhoons and other river basin units elsewhere in Taiwan and in the world. Indeed, the related discussions about these issues were really deficient in the original manuscript. Regarding the problems and limitations about the single-typhoon approach used in the study, we will add more discussions in the section 4.4 (Policy implications) in the revised manuscript.

5.P. 4, l. 2: I feel like you need more detail/consistency in your approach when it comes to the usage of terms, to better describe your conceptual framework (this is a comment also in light of the vague definition of vulnerability, please see a comment on that below). Here, what are biophysical elements, socioeconomic elements, industrial elements (aren't these belonging to socio*economic* elements?), "and land use elements" (sic!). Don't all these elements constitute some form of land-use? *Replies: In the manuscript, it really lacks detailed definition of the conceptual framework of vulnerability and some terms involved in our analyses. Thus, in the revised manuscript, the authors will further identify the key terms used in the analytical framework such as vulnerability and its components (e.g., exposure, biophysical context, socioeconomic sensitivity, land use and adaptive capacity). In particular, we will further clarify the pro-

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cess of building the conceptual framework of vulnerability, which would help us define the key components (and factors) of vulnerability.

6.P. 4, I. 5: What is meant with properties of a specific watershed context? *Replies: The properties of a specific watershed context mentioned here could mainly refer to hazard (for example, geology) attributes (they could also include ecology and institution contexts, but these properties would be beyond the scope of our discussion) other than vulnerability components. To clarify the wording of this sentence, we will replace “properties” with “hazard attributes” in this sentence.

7.The definition of vulnerability that is used by the authors remains vague. Please elaborate more on the concepts of exposure, sensitivity, adaptive capacity employed in your framework as shown in Eq. 1. I take it that, here, exposure refers to the UNISDR definition, i.e., elements potentially at risk? Also, later on, in Eq. 3, you refer to loss as a function of hazard and vulnerability. Thus, following your argumentation, e.g., I do not see averaged annual rainfall or debris flow as elements of the entity exposure (and, therefore, vulnerability), but rather as entities of the hazard (or hazard magnitude) used to determine affected (exposed) area/elements. I would also argue on the indicators elevation and proximity to rivers, which I do not see as an indicator for sensitivity. In order to clarify such issues, please elaborate in more detail on your conceptual framework/the definitions employed in your study. Also, if you argue that vulnerability frameworks need to be integrated, why didn't you investigate into additional, integrated frameworks of vulnerability? *Replies: The authors are so grateful for the referee's suggestions. In the manuscript, it really needs to elaborate more on the conceptual framework of vulnerability and its components. Therefore, in the revised version of the manuscript, we not only will increase more descriptions about how the conceptual framework of vulnerability was built, but also will add more explanations about the definition of exposure, sensitivity and adaptive capacity. First, we increase the discussions about the conceptual framework of vulnerability that was developed based on combining the vulnerability concept of IPCC (2014) with the risk-hazard approach (UNISDR,

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2013). This leads to conceptualize vulnerability as a function of exposure, sensitivity and adaptive capacity. Second, according to a combination of the concepts of IPCC and risk-hazard approach, we also define the components of vulnerability using a hybrid concept from these two approaches. We define exposure as “the presence of areas, system or assets in places and settings that could be adversely affected.” (IPCC, 2014). Thus, exposure can be considered as the nature and degree to which an area is exposed to climatic hazards. Moreover, sensitivity can be defined as “the degree to which a system is affected by climatic-related hazards” (IPCC, 2014). Based on these concepts, in our manuscript, “rainfall” and “debris flow torrents” are measured by long-term trends of an area exposed to flood hazard and debris flow torrents. However, as the referee’s comment, it is really better for considering the “biophysical context” indicators as a component of “exposure” than as an element of “sensitivity”. Thus, in the section 2 (particularly, 2.1 Vulnerability assessments) and section 3 (particularly, 3.1 Indicators of the vulnerability framework and hypotheses) of the revised manuscript, the authors will adjust “biophysical context” indicators from “sensitivity” dimension to “exposure” dimension in order to suit their definitions. The authors agree with the referee’s suggestions, so we use an indicator-based integrated approach to aggregate various components of vulnerability. Based on our hypothetical relationships between various indicators and vulnerability, we apply a multicriteria decision analysis (MCDA) procedure to aggregate various indicators to calculate the composite vulnerability index (CVI), which can represent the integrated vulnerability of each spatial unit (a village). In the section 3 (Methods and data) of revised manuscript, we will increase a figure (Figure 1) to help understand the procedure of assessing integrated vulnerability and to describe the stepwise procedure for linking local vulnerability assessments to hazard loss analyses.

8. In doing so, please also provide more insight into why the criteria listed in table 1 have been selected/how selection has been done. *Replies: The criteria used in our study are chosen based on our conceptual framework of vulnerability, literature review and the contextual characteristics of the river basin management. Especially, our definition

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of vulnerability and the selection of indicators refer to Hung and Chen (2013), which has been widely applied in the river basin vulnerability assessments in Taiwan. Thus, some processes of indicator selection were discussed in detail in Hung and Chen (2013). In the section 3 (Methods and data) of the revised manuscript, the authors will increase more descriptions to clarify the process of criteria and indicator selection.

9.P. 7, I. 18: It could be argued if increasing income etc. enhances coping strategies so that vulnerability is reduced, since an increase or accumulation of wealth etc. is typically also seen to increase vulnerability by increasing the values potentially at risk. *Replies: We would agree with referee's comments on the relationship between income and vulnerability. It is a reasonable relation between income and vulnerability concept. In fact, there is no common view about the relationship between income and vulnerability concept in the existing studies. In our study, we focus on a hypothesis of increasing income can be expected to enhance coping strategies. However, it needs to be examined by the case study. Finally, our case study showed that the areas with higher income would have lower typhoon losses than the other areas. But it is still in need of more case studies to reinforce the findings about the relationship between income, vulnerability concept and disaster losses.

10.P. 7, I. 23: If you argue that vulnerability is a multi-dimensional concept (which is not defined in the manuscript), I do not see how a preservation of (environmentally) sensitive (i.e., vulnerable?) areas leads to a decrease in vulnerability? *Replies: In the section 2.2 (Vulnerability and disaster losses) of the revised manuscript, the authors will define the multi-dimensional concept of vulnerability as that the components of vulnerability include various biophysical and socioeconomic factors of a specific river basin area. Moreover, we will also increase more explanations about how a preservation of environmentally sensitive areas leads to a decrease in vulnerability. In the study, the expectation is that a preservation of more environmentally sensitive areas would reduce urban, agricultural, and road developments, which could result in a decrease in vulnerability and lead to less disaster losses.

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11.P. 6, l. 12: What are the synergies and complexities that have been obtained and discussed by Hung & Chen? What is their relevance for the presented study? What is the “framework of vulnerability indicators” that is being referred to? As mentioned above, please elaborate more on your methodology and conceptual frame. *Replies: Many thanks for the referee’s suggestions. In the section 3.1 (Indicators of the vulnerability framework and hypotheses) of the revised manuscript, we will add more explanations about the relations between our study and Hung and Chen’s (2013) approach. Especially, we will elaborate more on the process of building the conceptual framework of vulnerability and the stepwise procedure for linking local vulnerability assessments to hazard loss analyses (by adding a figure to supporting the explanations).

12.In regard to Eq. 3, it is argued that using just one event (i.e., the typhoon Morakot) allows for the control of the “disaster scenario”, so that variation in loss can be attributed to variation in vulnerability. How do you control for hazard intensity as a governing factor of loss? Again, please provide more information on the methodology. *Replies: Indeed, there are some confusing descriptions in this sentence. Thus, it needs more explanations about the equation (3) to clarify its implications. In the revised manuscript, the sentence: “this approach allows disaster scenarios to be controlled, and which, other things being equal, any variation in losses directly are resulted from changes in hazard impacts and vulnerability factors. . .” will be reworded as “This approach allows us to concentrate on single disaster scenario, so that any variation in losses can be directly resulted from changes in hazard impacts and vulnerability factors. . .”. In addition, we will also add more explanations (by using a figure) about the procedure and methodology used in our study.

13.I have the impression that also the term hazard impact needs more clarification. Following table 1, hazard impact seems to refer to casualties, losses etc. However, in the manuscript, p. 9, l. 13, it is argued that the interaction of hazard impacts and vulnerability generates loss. In this case, wouldn’t impact refer to hazard intensity? *Replies: Indeed, some further clarification of the equation (3) is needed. Based on

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the concept of risk-hazard approach, we assume that disaster risk/loss is a function of hazard and vulnerability. In a long-term scale, it implies that hazard risk is the product of hazard and vulnerability. However, in a short-term or single hazard event scale within a specific region, it is a deterministic approach, which hazard can be varied with its different intensities and impacts on various areas. In our study, because we adopted a single hazard event approach, the hazard impact on various areas will be used for measuring “hazard” in the equation (3). This implies that the term “hazard impacts” has involved “hazard intensity” concept. The related explanations in the original manuscript are not clear enough. Thus, in the revised manuscript, we will reinforce the related discussions about the term “hazard” in the equation (3).

14. In table 1, you list various indicators per category. Please, describe what is the Mean/standard deviation referring to? Is, e.g., mean of population density equal to 2.74 inhabitants/km²/village unit? Isn't this number rather low, also considering your argumentation that the three river basins have approximately 1.26 mio. Inhabitants and an area of 7885km² (which would equate to approximately 160 inh./km²)? *Replies: The authors would like to appreciate the referee's reminders. In the revised manuscript, we will add a note to explain that the mean and S.D. are average and standard deviation values of the villages. On the other hand, the unit of “mean of population” is “thousand people” rather than the number of people. These revisions will be made in the revised manuscript.

15. Please provide more information on your indicators used to assess adaptive capacity. E.g., you mention the indicator “access to resources”. What is meant with this indicator? What resources, access in which way, etc., could you please provide more detail? How is the indicator operationalized? Also in this regard, what is the number of interviews in total, and what is N per river basin? *Replies: The interview data of the indicators used to assess adaptive capacity, including “risk perceptions”, “access to resources” and “adaptation appraisal”, were collected from a questionnaire survey of random sampling of the households for each village. This questionnaire survey

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was conducted by the National Science and Technology Center for Disaster Reduction (NCDR), Taiwan in 2004. The survey mainly aims to understand the extent of residents' hazard (e.g., flood, debris flow torrents) risk perceptions, hazard reduction and adaptive behavior as well as their determinants. The surveyed area included entire Taiwan, and the total sample size was 2,913. The related explanations about the questionnaire survey data was really deficient in the original manuscript. In the section 3 (Methods and data) and Table 1 of the revised manuscript, the authors will add more descriptions about these data and their sources.

16. Please elaborate more on the approaches that you classify as “top-down” and “bottom-up”. *Replies: In the section 2 (Vulnerability and disaster impacts) of the revised manuscript, the authors will increase more explanations about the differences between “top-down” and “bottom-up” approaches for linking vulnerability and disaster losses. In our study, we identify the “top-down” approaches focus on combining existing hazard loss theories (such as risk-hazard, PAR, PSR theory or MCDA) with computer-aid simulation and GIS-based analysis to project disaster losses. The “bottom-up” approaches concentrate on characterizing the distributions of disaster damage using historical or survey databases. However, these two types of approaches are often applied interactively rather than independently in the disaster damage (or risk) analyses. The related discussions were really rare in the original manuscript. Thus, in the revised manuscript, we will reinforce the related explanations in the section 2 (Vulnerability and disaster impacts).

17. Also, in regard to both approaches, you argue on the importance of connecting them, and on their “relative magnitude” (p. 5, l. 21). What is meant with that, what is relative magnitude? Furthermore, do you see both types of approaches as distinct, since you argue for a further integration of both? Isn't it the case, however, that “top-down” approaches also make use of empirical data (losses etc.) for validation of models, hence, integrate both approaches? *Replies: In the sentence “Increasing the understanding of the evolution of climatic disaster risk highlights the importance of

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connecting these two approaches and their relative magnitudes”. It is really not clear enough. Thus, in the revised manuscript, the authors will reword this sentence as “Increasing the understanding of the formation of climatic disaster risk highlights the importance of connecting aforementioned two types of approaches and their relative magnitudes in hazard risk analyses”. This would provide a clearer description. Really, as above mentioned, the distinction between the “top-down” and “bottom-up” approach is not absolutely clear and often used interactively. Our study aims to provide an approach to link these two types of approaches. Therefore, the terms “top-down” and “bottom-up” in the manuscript only provide a rough classification method for existing studies, which can help us identify the related contributions of our study. Finally, we will elaborate more on our approaches and related terms used in the manuscript.

18. Generally, please provide more details on your statistical analysis. I suggest you to include e.g. results as supplementary material if possible, e.g., correlation coefficients, etc. I assume that your analysis is carried out per river basin and per village unit, i.e., non-spatial? *Replies: In the revised manuscript, the authors will provide some supplementary materials, such as correlation coefficients, to help readers understand the results of some statistical analyses. Moreover, our analysis is conducted by per river basin (including entire three river basins) and per village unit. The spatial statistic analysis is majorly applied in the vulnerability assessments by using an MCDA procedure.

19. I find it difficult to interpret Spearman/Pearson r without knowledge on the shape of the distribution of indicators _ losses, as e.g. Pearson would only make sense in linear relationships. Do you find linearity? Again, what is N per river basin? *Replies: In reality, we are not very sure about whether or not the relationships between various disaster losses are linear. We assumed that there are linear relationships between these disaster loss items in order to simplify our analyses, although there are alternative methods to examine their relationships. Furthermore, we are also not really sure the distributions of disaster loss data are normal. Therefore, we simultaneously used Person correlation coefficient and nonparametric statistics (Spearman correlation co-

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efficient) to test their correlations. In the revised manuscript, we will increase more explanations about these assumptions.

20. Abstract, l. 8: Please rephrase “attack”. *Replies: We will reword and rephrase this sentence.

21. Introduction, P. 1, l. 24: Remove meanwhile. It sounds like 700 people were killed during the typhoon due to something completely different. *Replies: We will remove “meanwhile” and reword this sentence.

22. (*) P. 5, ll. 12-18: The paragraph is unclear to me. *Replies: The authors will reword and rephrase this paragraph to more clarify its discussions.

23. P. 10, l. 1.: Please rephrase, use e.g. people or inhabitants instead of populations. *Replies: We will replace “populations” with “inhabitants” in this sentence.

24. P. 10, l. 18: C4 I guess you mean administrative instead of geopolitical boundaries? *Replies: We will also replace “geopolitical” boundaries with “administrative” boundaries.

25. P. 11, l. 9: Do you mean spatially defined clusters? *Replies: This sentence will be reworded as “spatially-defined clusters of highly. . .”.

26. P. 12, l. 13: 93% of typhoon Morakot caused no damage or injuries. This sounds a bit odd. *Replies: This situation would result from our applying single typhoon event to characterize disaster loss distributions. It also causes us to use ZIP (zero-inflated Poisson) and ZINB (zero-inflated negative binomial) regression model to examine the determinants of disaster casualties. If more typhoon cases are considered, the distributions of typhoon injuries or fatalities would be more even. We will add more sentences about this situation in the discussions of our case study findings.

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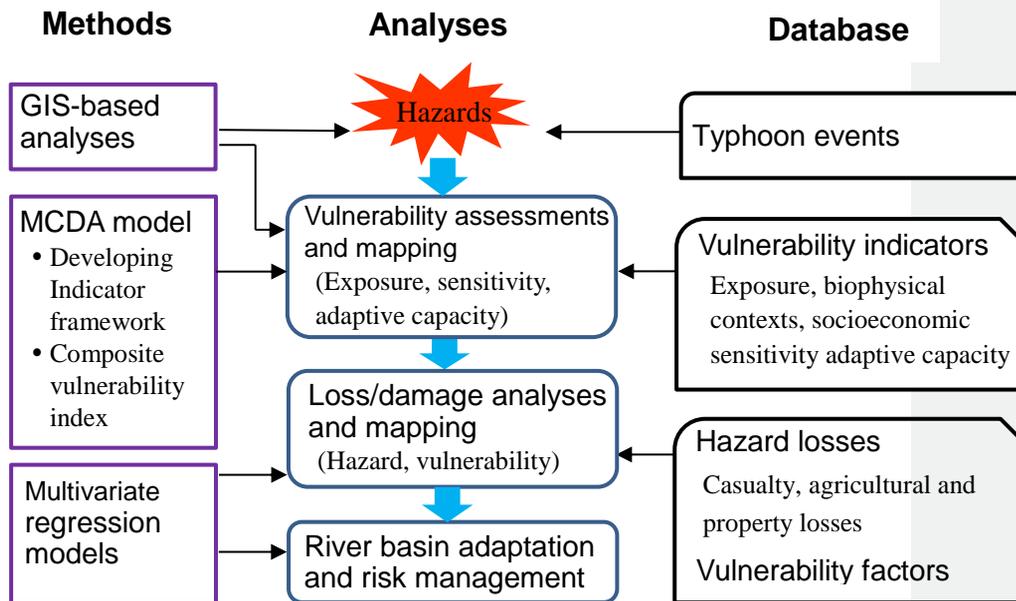


Figure 1. Stepwise procedure and framework of analysis

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