Multi-level assessment of flood risk perception and flood behaviour

Responses to reviewers

Response to Reviewer #2

Dear Reviewer,

We sincerely thank you for your thoughtful review of our manuscript. Your expertise in statistical analysis is evident in the depth of your evaluation, and we greatly appreciate the time and effort you invested in providing a detailed feedback.

We prepared a detailed point-by-point response to all your comments alongside the revised text. We sincerely appreciate your guidance in helping us refine this study.

Sincerely,

The authors

Detailed responses

1) Make sure the connection between risk perception and preparedness at different levels is clearly explained. This helps readers understand how findings at one level relate to another.

Answer: Thank you for this observation, which allowed us to help readers understand how findings at one level relate to another. In the introduction, lines 41- 48, the text was modified to:

Raaijmakers et al. (2008) identified three specific elements of flood risk perception, namely: awareness, worry and preparedness, and later Lechowska (2018) identified a so-called 'clear relation' between worry and awareness with flood risk perception, while relations between flood risk perception and preparedness was identified as an 'unclear relation', as well as the relation between worry and awareness with preparedness and between awareness and worry. In particular, preparedness can occur with specific cautionary measures corresponding to the different levels (see Veloso et al. 2022), i.e. having personal protective equipment at the individual level, having a power circuit above flood depth at the household level, implementing sandbag barriers at the neighbourhood level, implementation of shelters at the municipality level. Remarkably, at each level, preparedness is not clearly related to risk perception. Indeed, Scolobig et al. (2012) showed that the link between awareness and preparedness is not at all straightforward, as e.g. in the Italian Alps, residents felt both slightly worried about flood risk and slightly prepared to face an event. There was also a clear discrepancy between the actual adoption of household preparatory measures and the willingness to take self-protection actions among the studied localities.

2) Provide a brief explanation of the cluster analysis and PCoA methods in the methodology, so readers can follow these analyses without confusion.

Answer: Thank you for giving us the possibility to explain in more detail the PCoA methods. Therefore, Section 2.4.4 was expanded as follows:

2.4.4 Multilevel analysis: To explore similarities between neighbourhoods and municipalities based on the explanatory variables of worry and preparedness according to the multi-level regression, a principal coordinates analysis (PCO) was computed using Gower distance, which allows for the combination of ordinal and continuous data types. This method enabled the projection of multivariate dissimilarities into a reduced two-dimensional space while preserving the pairwise distances between observations as accurately as possible (Abdi and Williams, 2010). Subsequently, hierarchical clustering using Ward's method was conducted on the same distance matrix to identify groups of similar neighbourhoods and municipalities. For both spatial levels,

the input data were aggregated by either neighbourhood or municipality, averaging the relevant variables obtained in the multilevel regressions. This was combined with biplots that held to visualise scores plots (data points) and a loading plot (variable vectors) to simultaneously analyse row-sample relationships and column-variables contribution (Gower, 1995).

Additional reference:

Gower, J. C., & Hand, D. J. (1995). *Biplots* (Vol. 54). CRC Press.

3) Correct grammar errors and spelling mistakes: For instance, "neighbourghood" (appears multiple times, it should be "neighbourhood"), "preapredness" (line 481, it should be "preparedness"), "hydrologicalhydraulic" (line 484, it should be "hydrological and hydraulic"), "ackonwledged" (line 625, it should be "acknowledged").

Answer: We apologize for these issues. The manuscript was corrected accordingly.

4) The chart numbers do not match the references. For instance, "Figure 9 illustrates the flood behavior" (line 418), but the previous text only mentions Figures 1-6, indicating a numbering error.

Answer: We apologize for these issues. The manuscript was corrected accordingly.

5) The article uses a multilevel ordinal regression model to fit the relationships between the probability that the person belongs to a category of worry and age range of the respondent, trust in the neighbourhood, etc. (Equation 5). And also uses a multilevel ordinal regression model to fit the relationships between probability that the person belongs to a category of preparedness and the knowledge of flooding areas, the gender of the respondent, etc. (Equation 6). Has the author considered non-linear relationships? And the mutual influence among these factors, such as the socio-economic group and housing quality, etc.

Answer: Thank you for this important comment. Regarding non-linear relationships, most explanatory variables included in the multilevel ordinal regression models were specified as categorical or ordinal (e.g., age range, socioeconomic group, housing quality, trust levels). Therefore, the model does not assume a strictly linear relationship between these variables and the outcome, as each category is estimated separately. Concerning the mutual influence among variables, interaction terms were not included in the final models, as the multilevel structure already incorporates multiple variables across hierarchical levels, and adding interaction terms would substantially increase model complexity and reduce interpretability. Moreover, some variables used in the analysis (such as preparedness and ISMT) are composite indices that already integrate multiple dimensions. The primary objective of the study was to evaluate the independent contribution of variables at different levels rather than to model complex interaction effects.

6) The article employed linear methods such as Spearman coefficient analysis and Pearson's test to analyse the correlation between worry and preparedness. Did the author consider non-linear relationships?

Answer: Thank you for this comment. The relationship between worry and preparedness was analysed using contingency tables, Pearson’s chi-square test of independence, and Spearman’s rank correlation coefficient. These methods were selected due to the ordinal nature of the variables. Both worry and preparedness are ordinal measures, and therefore non-parametric approaches are more appropriate than linear correlation methods based on continuous assumptions. Spearman’s rank correlation does not assume a linear relationship between variables, but rather evaluates monotonic associations between ordinal variables. Similarly, Pearson’s chi-square test assesses statistical independence between categorical variables and does not rely on linearity assumptions. For these reasons, additional non-linear modelling approaches were not considered.

7) For the analysis of the relationship between flood risk perception and flood behaviour, the magnitude of the flood is a very important factor. Did the author consider the impact of different magnitudes of floods on the probability that the person belongs to a category of worry and the probability that the person belongs to a category of preparedness?

Answer: Thank you for this observation. We fully agree that the magnitude of the flood is a very important factor for the analysis of the relationship between flood risk perception and flood behaviour. As the available hydrological records (please see Figure 5) are insufficient for a formal frequency analysis of extreme discharges, the flood magnitude was classified between floods causing damages as reported in the news and

media, and floods without reports of damages. Therefore, to estimate the recurrence of flood events in each municipality, a review of national and regional news reports was conducted for the period 2000–2025. This search aimed to identify significant flooding over the last 25 years and to calculate the frequency of occurrence of a damaging flood, i.e. a flood reported in the news. Additionally, the dates of the floods detected in the literature were verified with the available discharge measured at gauge stations in Figure 5.