Multi-level assessment of flood risk perception and flood behaviour

Responses to reviewers

Response to Reviewer #5

Dear Reviewer,

We thank you for your dedicated comments and observations that helped us to enhance the quality of our MS. Below, we provide point-by-point responses to each of your comments. Line numbers refer approximately to the original manuscript. Some of your comments overlap with those from the other reviewers; where applicable, we intended to satisfy concerns raised by all reviewers to ensure a cohesive and integrated final manuscript.

Sincerely,

The authors

Detailed comments

1. Line 90: I miss the main objectives of the paper.

Answer: This observation is related to observation 5) by Reviewer#3, and to observation 1) by Reviewer#4. The text was modified to support statements with additional references, and to include both, a hypothesis and the main objectives of the paper as follows:

Spatial scale is crucial for understanding the relationship between risk and behaviour, as both worry and preparedness vary significantly across territories, while flood hazardousness is strongly conditioned by local factors (De Moel et al., 2015). Previous research has examined flood risk and behaviours mainly at the local scale, such as neighbourhoods (Al Assi et al., 2023) or municipalities (Becker et al., 2014; Santos et al., 2020). This article goes further by incorporating individual and household characteristics, allowing us to capture the multilevel complexity of space and its consequences for flood risk perception and adaptive behaviours. The hypothesis of this work is: "Flood behaviour varies differently with flood risk perception elements across different levels". To verify the hypothesis, the dimensions and variables that explain worry and preparedness at the different levels: individual, household, neighbourhood and municipality, and the relationships between worry and preparedness, as well as the flood behaviour, are analysed in four municipalities located along Chile, that represent different forms of urban agglomeration, ranging from small localities to intermediate cities within the national context. Thus, the main objectives of the study are: (1) to determine what are the variables explaining the elements of flood risk perception: worry and preparedness, (2) to explore the possible correlations between worry and preparedness at the different levels, and (3) to investigate what are the different flood behaviours that emerge from the interaction between the social and hydrological systems along the studied localities.

2. Line 102: Specify when exactly in the particular municipalities.

Answer: Thank you for your comment. The sentence has been revised to specify the years in which each municipality experienced flooding. Additional details are provided in Section 3.4 (Flood behaviour) and summarised in Table 8. The paragraph has been modified as follows: The study area corresponds to four Chilean municipalities that experienced flood events between 2000 and 2025: San Pedro de Atacama (2001, 2012, 2013, 2015, 2017, 2019, 2023), San Fernando (2000, 2006, 2015, 2023), Hualqui (2001, 2003, 2006, 2023, 2024), and Arauco (2001 [twice], 2003, 2006, 2008, 2019, 2023, 2024).

3. Line 115: Organize this data into a table.

Answer: Thank you for your comment. The data is now organized in a table and presented in the manuscript as follows:

Table 1. Average annual precipitation, flood-prone rivers, watershed areas, and average annual discharge by municipality.

Municipality	Average annual precipitation (range) (mm)	Rivers prone to flooding	Watershed area (km^2)	Average annual flow (m^3/s)
San Pedro de Atacama	42 (12 – 112)	San Pedro	933	0.8
		Vilama	379	0.2
San Fernando	670 (147– 1,230)	Antivero	443	7.6
		Tinguiririca	4,730	50.2
Hualqui	1,019 (269 – 1,664)	Biobío	24,264	955.0
		Hualqui	65	0.5
Arauco	1,143 (704 – 1,643)	Carampangue	1,262	61.5

4. Line 124: Organize this data into a table and standardize it for 2024.

Answer: Thank you for your comment. The data organized and standardized is presented in the manuscript as follows:

Table 2. Population, grow rate and housing units by municipality.

Municipality	Population (2002)	Population (2017)	Population (2024)	Total population growth (%)	Housing Units (2017)	Housing Units (2024)
San Pedro de Atacama	1,938	10,996	9,843	408%	4,144	5,071
San Fernando	63,732	73,973	75,585	19%	24,695	31,420
Hualqui	18,768	24,333	26,746	43%	7,754	10,881
Arauco	34,873	36,257	38,941	12%	11,663	13,185

5. Line 134: The characteristics of respondents and the method of their selection. Are these respondents whose homes were flooded? What is their experience and relevance to the floods? How was the data collected? At what level? What specific data was obtained? Was its reliability verified in any way?

Answer: Thank you for your comment. Section 2.2 has been revised and modified to:

The survey consisted of both open- and closed-ended questions and was structured around nine thematic dimensions: respondent characteristics, household characteristics, housing characteristics, location of the social network, experience during the most recent flood event, perception and knowledge of flood risk, collaboration networks, flood preparedness, and head-of-household characteristics.

Across the study areas, zones for survey application were pre-selected based on their flood exposure within the four municipalities. The household was defined as the unit of analysis. Surveyors selected households where an adult resident agreed to participate, typically following a non-consecutive pattern of household.

The questionnaire was administered in 2024 using Pen and Paper Personal Interviews (PAPI). A total of 1,015 surveys, each comprising 80 questions, were conducted. After data cleaning and validation, 1,007 responses were retained for analysis. The final sample distribution was as follows: 252 households in San Pedro de Atacama, 380 in San Fernando, 100 in Hualqui, and 275 in Arauco. Considering the population size and the homogeneity of residents aged 18 and over in each municipality, the sample design ensured a 95% confidence level with a maximum margin of error of 5%.

6. Line 150: How were respondents selected according to this factor? Were they divided into uniform clusters for all municipalities?

Answer: Thank you for this observation. We have clarified the household selection process in Section 2.2. The distance from each household to the nearest overflowing river was used for further statistical analysis. In addition, respondents were not divided into uniform clusters.

7. Line 155: Why are you using some census data from 2024 earlier?

Answer: The population figures reported for 2024 correspond to the most recent official projections available from the National Institute of Statistics (INE), and are used only for descriptive purposes to characterize the current demographic context of the municipalities.
In contrast, structural socio-material variables such as the Territorial Socio-Material Index (ISMT) were computed using the 2017 Census, which is the most recent full census dataset available at the block level. These indicators capture relatively stable structural conditions (housing quality, overcrowding, education level of the head of household, etc.), which are not expected to change substantially in the short term.
The combination of updated demographic projections with census-based structural indicators ensures both temporal relevance and methodological consistency.

8. Line 267: What is interesting on this? It strongly depends on the respondents selection of the authors. This is not a result, this is a characterization of respondents and their selection.

Answer: Thank you for this observation. We agree, therefore the text was rephrased as follows:

According to our results, 57.9% of the surveyed people live closer than 750 m from the river, i.e. in areas with a high exposure to flood, 84.7% declare to know the flooding areas, and 55.4% experienced a flood passing outside the home. Overall, 96.2% of all respondents live closer than 750 m from the river, declare to know the flooding areas, and/or experienced a flood passing outside the home. Thus, in the present study people were assumed to be aware of flood risk.

9. Line 396: What does it mean neighbourhood?

Answer: In this study, neighbourhoods were defined using an official Geographic Information System (GIS) layer of unidades vecinales (neighbourhood units) in Chile. These units constitute the geographical counterpart of juntas de vecinos (neighbourhood councils), which are the legally recognised base of local social organisation in the country. As such, neighbourhood units represent administratively recognised territorial subdivisions that also function as socially meaningful spaces for community organisation, participation, and local governance.

To integrate statistical information available at the census-block level (manzanas censales), neighbourhood boundaries were spatially adjusted through a GIS overlay procedure. Census blocks were aggregated according to the limits of the corresponding neighbourhood units, ensuring consistency between socio-demographic statistical data and territorially recognised neighbourhood areas.

This approach allows combining two complementary logics: the administrative community definition embedded in neighbourhood units. Particularly relevant for variables related to social cohesion, trust, and local interaction, and the statistical robustness provided by census-block data, which offer detailed socio-material information.

In the Chilean context and more broadly in the urban studies literature there is no single, universally accepted definition of “neighbourhood.” Rather, neighbourhoods are typically conceptualised as hybrid constructs that combine administrative delimitation and community-based recognition. The operationalisation adopted in this study follows this combined perspective, aligning territorial-administrative boundaries with socio-spatial meaning.

10. Line 438: What does "close to the river" mean? How are the results affected by this distance? And how about experience with floods?

Answer: Thank you. In this case, "near the river" means that the house is located less than 750 m from the main river that overflows. Distance to the river was considered as a proxy for exposure and visibility of the

hazard. As noted in the manuscript, proximity to rivers has been associated with increased awareness due to greater hazard visibility (Gray-Scholz et al., 2019; Ali et al., 2022). Furthermore, knowledge of flood-prone areas is widely recognised as an indicator of awareness (Mondino et al., 2020; Bradford et al., 2012). In this context, households located closer to the river are assumed to have greater exposure to flood dynamics and therefore higher likelihood of awareness.

11. Line 475: Doubled.

Answer: Thank you. The issue was corrected in the MS.

12. Line 508: How are these results affected by the number of floods and their intensity?

Answer: Thank you for this observation which is in line with comment 8) by Reviewer#2 and comment 18) by Reviewer#3. 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. After Line 508 we added: This study provides an innovative multilevel perspective on flood risk perception and behaviour, yet some aspects should be noted. Flood risk perception and flood behavior were analyzed in relation to damaging floods that occurred in the past and were reported in the news and social media. Future research could study more deeply the effects of flood magnitude on the obtained results.