	Comment	Answer
Reviewer #1		
General Comments	This manuscript addresses a critical topic in natural hazard research, focusing on the relationship between adaptive capacity and adaptation action in the context of pluvial flood risk in Southern Germany. The study's attempt to differentiate between generic and specific adaptive capacity indicators and their impact on household adaptation measures is commendable. However, there are remaining issues that need to be addressed before the paper can be considered for publication.	We appreciate the time and effort you dedicated to provide feedback on our manuscript and are grateful for the insightful comments and valuable improvements to our paper. We diligently went through your remarks and corrected our manuscript accordingly.
Specific Comments	**1. Theoretical Framework and Indicator Selection**:	We greatly appreciate your insightful comments regarding the theoretical framework and indicator selection in our study. Following further discussion within the author team, we decided to undertake more substantial revisions in Chapter 2 than those initially outlined in our response from October. In summary, we - Renamed the title from "Conceptualising adaptive capacity" to "Conceptualising *and measuring* adaptive capacity" to emphasise that the chapter also discusses the indicator selection - Reorganized the chapter and divided it into two distinct subsections: "2.1 Evolution of the concept" outlines the evolution of the concept and how its understanding has changed over time. This was already part of the first draft. "2.2 Identifying adaptive capacity indicators" was newly developed in response to the reviewer's helpful suggestions. It provides a detailed account of our literature-based indicator selection process. Additionally, we have included a new table in the Appendix (A1), which summarises the literature used for our conceptualization and indicator selection. Furthermore, Table 1 has been expanded with an additional column to indicate the relevant theoretical frameworks for each indicator.
	• The paper lacks a clear theoretical foundation for the selection of adaptive capacity indicators. Please provide a comprehensive literature review that explains the theoretical basis for using these	We have addressed your comment in the newly created subsection "2.2 Identifying adaptive capacity indicators". Our indicator selection process builds on previous literature, focusing

	indicators. Perhaps authors can justify why you chose to focus on indicators rather than established theories of adaptive behavior.	specifically on studies that explicitly address the concept of adaptive capacity and the capacity-action relationship. This approach aligns with our study's aim to test the usefulness of commonly employed adaptive capacity indicators as proxy for adaptive behaviour. While many adaptive capacity indicators can be linked to established theoretical frameworks (mainly focusing on explaining adaptive behaviour), we found that surprisingly few empirical adaptive capacity studies explicitly reference these theories. To clarify that several of the indicators in our study are indeed grounded in theoretical frameworks, we have added an additional column to Table 1, specifying the relevant theoretical frameworks for each indicator. Furthermore, we added Table A1 in the Appendix, which provides an overview of the two bodies of literature that informed our indicator selection (see our response to the next comment for more details).
	• Add a detailed section explaining how each indicator (both generic and specific) was selected, defined, and operationalized. This should include: a) The rationale for including each indicator b) How each indicator is measured (e.g., survey questions, scales used)	Thank you for pointing this out. Some of the information you mention is already presented in Tables 1 and 2. Unfortunately, both tables are not correctly positioned in the current template. We will ensure that both tables are correctly positioned within the text (and not after the references) in the final manuscript. To address your helpful comment, we have made the following revisions: a) We have added a paragraph in subsection 2.2 that outlines our indicator selection process in more detail: *Based on the literature review, we compiled a comprehensive list containing 49 indicators drawn from the capacity-action studies presented in Table A1, regardless of conflicting findings or null results. To ensure comparability, we focused our indicator selection exclusively on the quantitative empirical studies examining the capacity-action relationship. A cross-check confirmed that these indicators are also supported by the highly cited literature. In contrast to other studies (e.g., Grothmann and Patt, 2005; Barnes et al. 2020), we chose not to consider personal characteristics such as age, migrant background or sex of the primary decision-maker in the household, as these factors are*

		unalterable and not necessarily representative for the household as a whole. After grouping indicators that refer to the same indicator but use different terms (e.g., social connectivity and bonding social capital), we discussed the relevance of the resulting 32 indicators for the German context within the author team. Fourteen indicators were excluded as they specifically referred to resource-dependent communities. For example, while livelihood diversification is often understood as a form of flexibility in societies with a natural resource-based economy, we deemed this capacity not relevant in our study setting. *This process resulted in 18 indicators representing adaptive capacity of households in the German pluvial flood context.* b) The scales for each indicator are already presented in Table 2. To clarify that our questionnaire (containing both questions and answer options) is available as an open-access resource, we have added a sentence in the method section (line 124): This process resulted in a questionnaire with an average length of 36 minutes which covered a broad range of topics such as perceptions about climate change and extreme weather events, risk awareness, pluvial flood damage and event characteristics, private flood risk adaptation measures, housing characteristics, and sociodemographic characteristics*. The questionnaire is openly available (Schubert et al. 2024).*
	• Provide a more comprehensive review of previous findings on both generic and specific indicators. This could include: a) A summary table of key studies, their indicators, and main findings. b) Discussion of any conflicting results in the literature and how your study addresses these conflicts.	Thank you for your suggestion to strengthen our manuscript by making more explicit references to the literature. In response to your feedback, we have made the following revisions: a) We have added Table A1 in the Appendix, which provides an overview of the two bodies of literature that informed our indicator selection. Table A1 summarises the study's context, the indicator selection process (theoretical framework/literature-based), the adaptive capacity indicators used in the study and our key takeaway.

		Additionally, we have revised the discussion section, where we now explicitly reference these key studies and discuss our findings in relation to them. We added the following lines on page 26: Line 365: Owning a property as well as having a larger social network makes flood risk adaptation more likely; both effects are also well documented in the adaptation literature (for ownership, see Grothmann and Reusswig 2006, Kuhlicke et al. 2020, Dillenardt et al. 2022; for social network, see, for example, Adger 2003, Pelling and High 2005). *Similar positive effects for social capital have also been reported in the capacity-action literature (Barnes et al. 2020, Bartelet et al. 2023).* Line 368: The finding that neither wealth nor income are drivers of adaptation action at the household level is consistent with studies on household flood adaptation in Germany (Grothmann and Reusswig 2006, Dillenardt et al. 2022), *as well as previous findings on the capacity-action relationship (Mortreux et al. 2020, Barnes et al. 2020, Green et al. 2021).* Line 378: The importance of these factors has also been demonstrated in recent meta-analyses (Bamberg et al., 2017; van Valkengoed and Steg, 2019), various flood-related studies (e.g. Grothmann and Reusswig, 2006; Bubeck et al., 2023; Dillenardt and Thieken, 2024) *and within the capacity-action literature (Mortreux et al. 2020, Barnes et al. 2020, Bartelet et al. 2023).* b) Thank you for this suggestion. We think that the available studies on the capacity-action relationship – the central focus of our analysis – currently hardly allow for a comparison. We included the following paragraph in chapter 2.2 to make that finding more transparent: *For empirical studies examining the capacity-action relationship, we identified only a small number of studies. They use diverse sets of indicators, with partial overlaps, reflecting the wide variety of*

		study contexts (for an overview, see Table A1). Consequently, findings are difficult to compare across case studies and strategic meta-studies are still lacking. We additionally want to point out that we included all indicators in our review, irrespective of conflicting findings or null results. We therefore included the following statement in chapter 2.2: *Based on the literature review, we compiled a comprehensive list containing 49 indicators drawn from the capacity-action studies presented in Table A1, regardless of conflicting findings or null results.*
	2. Methodology: • Regarding the missing data: The assumption that income data is Missing At Random (MAR) is a crucial one that requires careful consideration. Income data often has patterns of missingness that may be related to the income levels themselves, potentially making it Missing Not At Random (MNAR). I suggest followings: a) Describing any tests or analyses performed to investigate the missing data mechanism, b) Discussing the plausibility of the MAR assumption for income data in your specific context. c) If you suspect the data might be MNAR, consider discussing potential implications for your analysis and results.	We fully agree with you that this point was not presented explicitly enough in our manuscript. We explored the missing data patterns and mechanisms with graphical diagnostics provided by the VIM package (Templ et al. 2012). More specifically, we used matrix plots, margin plots and mosaic plots to detect relationships between the values of different variables and the propensity to be missing (see Rcode 04-imputation-missing-data.R in the assets section). However, "it is not possible to test MAR versus MNAR since the information that is needed for such a test is missing" (van Buuren 2018, p. 36). To make the MAR assumption more plausible, we estimated a predictor matrix and included all correlated variables as predictors (van Buuren 2018, p.167). E.g. for the income variable, 33 variables were used to predict missing values, amongst them variables such as age, gender, education and living area. While we can explain parts of the missingness with the imputation models, you are indeed right that is very likely that another part remains unexplained (MNAR). However, this is not problematic for two reasons. Firstly, a simulation study has demonstrated that multiple imputation is remarkably robust against MNAR (Collins et al. 2001). Secondly, even when falsely assuming MAR, results are still less biased than a complete case analysis, which would only be unbiased under MCAR (van Ginkel et al. 2020). We decided to add a short paragraph about the MAR assumption to our revised manuscript, thereby discussing the assumption in

		general and not only with reference to the income variable. The following sentences is included in line 159: *Missing data patterns and mechanisms were explored with graphical diagnostics from the VIM package (Templ et al. 2012). Multiple imputation generally starts from assuming a missing at random (MAR) mechanism (van Buuren 2018, p. 165). To make this assumption more plausible, we estimated a predictor matrix and included all correlated variables as predictors (van Buuren 2018, p.182). Since distinguishing between MAR and missing not at random (MNAR) is not possible (van Buuren 2018, p. 36), we cannot rule out the presence of MNAR in our data. Nevertheless, multiple imputation is remarkably robust against MNAR (Collins et al. 2001), and even if MAR is falsely assumed, estimates remain less biased than those from a complete case analysis (van Buuren 2018, p.57).*
	• To demonstrate the robustness of your findings, I suggest presenting a sensitivity analysis such as with and without imputed data (complete case). This could go into Appendix.	We are happy to provide the results of the complete case analysis in the Appendix. Overall, the results are similar; however, the models using imputed data show more pronounced effects, with stronger effect sizes and smaller p-values. Nevertheless, we prefer not to frame this as a sensitivity analysis for two reasons. First, the complete case (CC) regression models suffer from a loss of statistical power. This is particularly evident in models M3 and M6 (tenant models), where the sample size is too small given the large number of predictors. Second, the complete case results are likely biased due to the violation of the MCAR assumption (see also the previous comment). Therefore, comparing the imputed and complete case results does not provide meaningful insights into the robustness of our findings. We have added Table C2 in the Appendix and the following paragraph in line 162: *We also analysed the subset of complete cases and obtained similar findings (see Appendix C2). A comparison of the p-values and effect sizes reveals that the multiple imputed models (Appendix C1) are more efficient than a complete case analysis.*
	3. Results and Discussion:	Thank you for this suggestion, which was also brought up by the second reviewer.

	• In the discussion section, elaborating more on the practical implications of your findings for policy makers and flood risk managers could enhance the section.	We have added the following paragraph on policy implications in the discussion section of the revised manuscript (line 431): *5.4 Policy implications* *Based on our findings, we recommend two key policy measures to enhance local adaptive capacity and household adaptation efforts: a) promoting local adaptation information and participation initiatives (e.g., led by municipalities) to strengthen risk awareness and self-efficacy among citizens, and b) creating targeted funding programs or financial incentives aimed at supporting low-income households.* *Our results demonstrate that measures which increase specific capacity are key and benefit all societal groups. Risk perception and previous risk experience are the strongest drivers of adaptation actions for both homeowners and tenants. Unlike generic capacity, specific capacity, such as risk awareness, "can potentially be altered within the short to medium term, and the power to do so lies at least partially with local policy makers" (Werg et al., 2013, 1614). Municipalities could play a key role in this, for example by hosting information events to inform citizens or by sharing experiences of affected residents and successful adaptation efforts. However, recent surveys and research show that the majority of German municipalities are still not actively informing citizens about flood risks and protection measures (von Streit et al., 2024; Friedrich et al. 2024), let alone engaging them in risk management (Wamsler, 2016).* *Another major finding of our study is that income groups in our sample differ in how they translate their financial assets into adaptation actions. This suggests that undifferentiated distribution approaches like tax incentives or public funding may be less effective than differentiated measures and interventions targeting underprivileged groups. While medium- and high-income households have the financial capacity to implement adaptation measures, they often fail to fully realise this potential due to a lack of specific capacity. For these groups, policy should focus on enhancing risk awareness, self-efficacy, and motivation for protective action, whereas funding programmes are crucial for*

		low-income households to enable the implementation of more costly adaptation measures.
	4. Presentation Improvements: • At the beginning of each analysis section, add a brief paragraph or sentences stating the purpose of the analysis and how it relates to your overall research questions.	We acknowledge that additional guidance would help readers navigate the results section. Therefore, we have added the following introductory paragraph to Section 4 Results (line 182): *To explore whether adaptive capacity translates into adaptation, we first take stock of the households' adaptive capacity and adaptation actions in our sample using descriptive statistics. Subsequently, we utilise correlation and regression analysis to examine how adaptive capacity influences households' decisions to implement pluvial flood adaptation measures.*
	• Consider renaming "specific capacity" to a more descriptive term.	While we appreciate the reviewer's feedback, we have respectfully decided not to universally rename "specific capacity." The term was introduced in a highly cited paper by Eakin et al. (2014) and is widely recognized in the field, as well as utilised in IPCC assessment reports (e.g., Castellanos et al. 2022, p. 1748). However, we acknowledge the importance of being precise regarding the specific hazard examined. Therefore, we have replaced the term "specific capacity" with "*flood*-specific capacity" in the captions of Figures 6 and 7 and in Appendix C.
	• Average duration of residence cannot be fully translated as place attachment. I would state it as "average duration of residence" only.	Thank you for pointing this out. We have changed the term in the text body and all figures and tables to "*planned duration of residence*".
Technical Comments	• Please specify the software used for statistical analyses.	We have added the following sentence in line 181: *All analyses were performed with the statistical software R (Version 4.3.1).*
	• Line 140: Please include the actual response rate figure in the body text.	We have added the response rate in line 140 as follows: Despite efforts to increase the response rates such as a mixed-mode design, response rates were rather low (*8 % for the randomly selected households and 5 % for the purposive sample*).

Reviewer #2 Samar Momin		
General Comments	The article titled "Unravelling the capacity-action gap in flood risk adaptation" clearly reflects the contents of the paper, and the abstract provides a concise, complete, and unambiguous summary of the work done and the results obtained. Both these sections are pertinent and easy to understand. The manuscript is well-written and well-structured, delivering the idea, methodology, and results clearly and concisely. The figures are descriptive and of high quality, and the tables are informative. It is well-referenced with proper credit attributed to previous and/or related works, and the authors clearly indicate each of their contributions. The manuscript contributes a new and interesting methodology to analyze the adaptive capacity and subsequent adaptive behavior of German households towards urban pluvial flooding. It focuses on an affluent and dynamically growing urban-rural region in the vicinity of Munich, Southern Germany. This region serves as an example of areas with increasing heavy precipitation events and pluvial flood risks. Estimating such adaptive capacities is extremely important for comprehensive disaster risk management strategies. Thus, this manuscript has excellent scientific significance, scientific quality, and presentation quality.	Thank you very much for taking the time to review our manuscript. We are grateful for your positive feedback regarding our work and appreciate the specific issues you raised and the valuable questions you have posed.
Specific Comments	**1. Methodological Limitations:** • The authors state that "Our study suffers from nonresponse patterns…" and "due to a low response rate." **Question 1**: If 1,571 responses are considered a low response rate, what number of responses would be considered desirable?	Thank you for pointing out that our sentence in line 140 about the low response rate is misleading. The overall number of responses (n = 1,571) is sufficient to ensure statistical power; however, we had to invite many households to achieve this number. In line 140, we refer to the response rates indicated in Figure 3. To make that more clear, we add the response rates in line 140: Despite efforts to increase the response rates such as a mixed-mode design, response rates were rather low (*8 % for the randomly selected households and 5 % for the purposive sample*).
	2. Issues with Online Survey Approach: • Future natural disasters are likely to increase, necessitating better ways to reach the population. **Question 2**: Given that most households were educated, wealthy, and informed, why did the online approach (i.e., link shared in local newspapers and Facebook advertisements) not perform well?	Thank you for this very interesting question. Unfortunately, it is not possible to calculate an exact response rate for the publicly available questionnaire (convenience sample), as we do not have data on the number of households that saw the ads. Even though respondents from the convenience sample could also choose between an online questionnaire or a telephone interview, most respondents opted for the online version. While we do have some metadata from the Facebook ad (e.g. impressions, clicks), it

	Question 3: Could the authors elaborate on potential improvements in data collection methods or strategies to convert non-responses into responses, aiming for a response rate exceeding 50%?	remains speculative why this innovative method yielded rather disappointing results. One possible explanation could be the generic and non-personalized nature of the advertisement. Survey response rates have been declining significantly over time, and even large-scale survey programs that employ high-quality methodologies nowadays rarely achieve response rates exceeding 50% (see, for example, ESS 2024). Numerous studies have explored strategies to increase response rates, including offering different response modes (such as mixed-mode surveys), optimizing questionnaire length, carefully crafting the wording of invitation letters, providing incentives, and adjusting the timing and frequency of reminders (e.g. Groves et al 2009, p. 201f.). However, the implementation of these strategies is highly dependent on available resources, particularly time and budget constraints. In our household survey, we employed several of the already outlined strategies and mentioned them in the manuscript, including a mixed-mode design and pretests to refine the questionnaire (see lines 128 & 140).
	3. Engagement of High-Earning vs. Low-Earning Respondents: • It seems that the high-earning respondents might be even less likely to implement private measures than the low-earning. • This aligns with the higher risk-taking capacity of high-earning respondents compared to low-earning respondents. **Question 4**: Shouldn't the surveys be targeted to reach more low-earning (or low-risk taking) respondents more effectively?	Indeed, increasing the number of low-earning respondents should be an important aim of future surveys to test exactly the hypothesis you mentioned. Including "hard-to-reach" subgroups such as those living in vulnerable social and/or economic situations in survey research is often difficult due to sampling issues and individual barriers to participation (Ellard-Gray et al. 2015). As exploring income effects was not the primary objective of our study, we did not establish a quota for high-/low-income households. Even though low-income households were generally underrepresented in our survey (see Appendix B1), our data-driven classification of low- and high-earning households based on quantiles (15% and 90%) allowed us to estimate coefficients for the subgroups. For clarification, we added the following two sentences in line 331: Additionally, we account for differences between income groups. *Households with an equalised disposable net income below 1,300*

		€ (10% quantile) were classified as low-income, between 1,300 € and 4,000 € as middle-income and above 4,000 € (85% quantile) as high-income. These data-based income groups are roughly in line with official classifications for Bavaria (Niehues et al. 2023, p. 37).
	4. Natural Hazard Insurance Coverage: • The most popular measure for both owners and tenants is to take out natural hazard insurance coverage for the building and/or contents (72% and 26%, respectively). • Assuming that 72% of owners bought natural hazard insurance, they are likely to be well-informed about measures to help reduce the economic impact of flooding, even if they are imposed by the requirements of the insurance policies. • However, analysis and existing research (Eriksen et al., 2020) suggest that being well-informed is not necessarily the case. • Generic capacity seems to be a necessary, but not sufficient, condition for adaptation (Eakin et al., 2014, p. 5), meaning that affluence alone will not suffice to cope with climate risks. **Question 5**: Could the authors provide further insights on why affluence alone is not enough for effective adaptation and what can improve practical adaptation strategies?	Thank you very much for pointing out that we could strengthen our manuscript by elaborating more on the practical relevance of our findings. A similar comment was also brought up by the other reviewer. We have added another paragraph on policy implications in the discussion section (line 431), also taking into account the thoughts you provided in your comment on Policy implications. *5.4 Policy implications* *Based on our findings, we recommend two key policy measures to enhance local adaptive capacity and household adaptation efforts: a) promoting local adaptation information and participation initiatives (e.g., led by municipalities) to strengthen risk awareness and self-efficacy among citizens, and b) creating targeted funding programs or financial incentives aimed at supporting low-income households.* *Our results demonstrate that measures which increase specific capacity are key and benefit all societal groups. Risk perception and previous risk experience are the strongest drivers of adaptation actions for both homeowners and tenants. Unlike generic capacity, specific capacity, such as risk awareness, "can potentially be altered within the short to medium term, and the power to do so lies at least partially with local policy makers" (Werg et al., 2013, 1614). Municipalities could play a key role in this, for example by hosting information events to inform citizens or by sharing experiences of affected residents and successful adaptation efforts. However, recent surveys and research show that the majority of German municipalities are still not actively informing citizens about flood risks and protection measures (von Streit et al., 2024; Friedrich et al. 2024), let alone engaging them in risk management (Wamsler, 2016).* *Another major finding of our study is that income groups in our sample differ in how they translate their financial assets into*
	5. Policy Implications: • This could involve mandatory flood insurance or tax incentives for implementing flood protection measures. • To improve response rates in future surveys and ensure a more representative sample, policymakers and researchers could collaborate on developing more effective outreach strategies, such as integrating surveys with community events, engaging with school and university students, and leveraging social networks.	

		adaptation actions. This suggests that undifferentiated distribution approaches like tax incentives or public funding may be less effective than differentiated measures and interventions targeting underprivileged groups. While medium- and high-income households have the financial capacity to implement adaptation measures, they often fail to fully realise this potential due to a lack of specific capacity. For these groups, policy should focus on enhancing risk awareness, self-efficacy, and motivation for protective action, whereas funding programmes are crucial for low-income households to enable the implementation of more costly adaptation measures.
Technical Comments	**1. Information Obtained by Households**: • Similar to Rözer et al. (2016), our results hint that information is more frequently obtained by those households who already experienced a pluvial flooding event. **Question 6**: Is there a better way to phrase this statement without using the word "hint"	We replaced the word "hint" with indicate (line 225): Similar to Rözer et al. (2016), our results *indicate* that information is more frequently obtained by those households who already experienced a pluvial flooding event.
	2. Sample Size and Complete Cases: • The sample size increased from 1,020 complete cases to 1,571 households. **Question 7**: What does "Complete cases" refer to? Clarifying this term helps readers understand the completeness and reliability of the dataset.	Thank you for pointing out this issue. We clarified the term by adding the following explanation in line 162: By this means, the sample size increased from 1,020 complete cases (*without missing data on the variables of interest*) to 1,571 households.