Response to Reviewer 1

We are grateful to the reviewer for putting in a lot of effort and dedicating time to reading and analysing the manuscript, and for the useful and insightful review comments that definitely improved the outcome of this paper. We committed to diligently addressing the comments, and we hope that we succeeded in satisfying the exigencies and the high academic standards of the reviewer.
Please find below the point by point responses.

The reviewers' comments are written in italics, and our responses in regular font. *We chose blue and italic formatting for citations from the manuscript.*
All of the line numbers refer to the reviewed version of the manuscript.

R1: *While the topic and methodology of the paper present some interesting and novel ideas, i feel the manuscript needs a significant amount of work and restructuring before it can be published in NHESS, which i why i am suggesting major revisions to the manuscript. The main challenge is that this paper tried to do too much. It is hard to follow the narrative/ red thread, and i found myself getting lost in the many steps of the methodology, which is rather eclectic in nature. I feel the paper could benefit from a reduction in steps and aims, which would then link the methods to the results more clearly.*

Response: Indeed, the manuscript was restructured according to the new aim outlined below in order to streamline the understanding of the presented ideas and facilitate the identification of the red thread. We acknowledge the extensive content of the methodology, and contracted it to 72.22% of its initial length (from 2517 to 1818 words), removing the subsection called Exploring the Impact Chain as well as other paragraphs in the other 2 subsections, and consequently amending the methodological workflow figure (Figure 3).

By removing one of the two initial objectives of the paper (the one relating to the exploration of multi-hazard impacts), the operation with two Impact Chains (one for the first objective, and one for the second) became unnecessary. Therefore, the paper relies on a single, enhanced Impact Chain, which builds on an initial version developed within the Paratus Project. All particular changes are highlighted by track changes in the manuscript.

Overall, we reduced the size of the paper to 78% of its initial size, from 13 252 words to 10 336 words (without references).

Major comments

Introduction

R1: *The introduction needs significant restructuring and rewriting to draw out the main research gap and aims that the paper is trying to close. The use of non-technical language makes it hard to follow. Review the use of sentences such as the following.*

- The third decade of the 21st century debuted with a pivotal epidemiological hazardous event that taught human communities worldwide formative and often cruel lessons.

- In the new multi-hazard-prone era

Response: In the reviewed version, the Introduction was restructured following the guidance of the reviewer in order to streamline the comprehension of ideas.
We modified the indicated phrases, as well as others that display the same shortcoming. Also, the entire manuscript was checked to remove such formulations.

The main research gap is extensively presented in two paragraphs, lines 82-94: *Up to date, scientific works on the interactions between natural hazards and the COVID-19 pandemic have primarily revolved around factual observations, overlooking the effects on the dynamics of vulnerability. Many examples (e.g., Andrews 2020, Majumdar and Dasgupta 2020, UNDRR 2020, Kassegn and Endris 2021, Mangubhai et al. 2021, Mishra et al. 2021, Patwary and Rodriguez-Morales 2021, Pramanik et al. 2021, Izumi and Shaw 2022) pertain to hydro-climatic hazardous events amid the pandemic, offering only factual documentation on their interactions. Narrowing down to the flood hazard, the compounded impacts of flood events and the pandemic are largely unknown and have been described only tangentially or in short (Simonovic et al. 2020, Patwary and Rodriguez-Morales 2021, Pramanik et al. 2021, Turay 2022), although the pandemic can augment typical health-related flood impacts (e.g., injuries, gastric problems stemming from water contamination, increased stress and/or anxiety) (Simonovic et al. 2020). Instead, more literature is available on the potential effects of flood events on the dynamics of COVID-19 cases (Frausto-Martínez et al. 2020, Mavroulis et al. 2021a, b, Albulescu 2023). What is more, the augmentation or attenuation of vulnerability conditions by previous hazard impacts (be they floods, pandemics, or other hazards) was not considered in any case study and has only been documented related to long-term processes (de Ruiter and van Loon 2022).*

This research gap-related paragraph is followed by the paragraph with the aim of the study (see below).

R1: *The main sentence and aim of the paper is hidden "This study delves deeper into the changes in vulnerability under hazard-generated impacts, taking as a case study two co-occurrent, independent hazards (i.e., floods and the COVID-19 pandemic) that severely affected a European country." and the current text does not speak so much to this. The introduction should be restructured to present the challenge, gap and how your work supports closing it.*

Response: The aim phrase starts the paragraph at line 95-99. It was contracted to focus on the augmentation of vulnerability by impacts and adaptation options in the proposed multi-hazard context: *This study aims to address the research gap regarding the dynamics of vulnerability in a multi-hazard context by analysing the increases in vulnerability that stem from hazard impacts and adaptation options, taking as a case study the co-occurrent extreme river flood events and the COVID-19 pandemic in Romania of 2020 and 2021.*

The Introduction was restructured as indicated by the reviewer: the challenge (lines 42-81), the gap (lines 82-94), the aim (95-108), and the contribution of the paper to the effort of reducing the gap (109-119). This structure is briefly presented at lines 42-50: *Given the increased frequency of co-occurrent or cascading hazards, vulnerability consolidated its key position in multi-risk analysis because the impact of multiple hazards and adaptive strategies reshaped its spatial and temporal dynamics. This raises significant challenges for risk management while reinforcing vulnerability's role in portraying disasters as human constructs (de Ruiter and van Loon 2022). This study delves deeper into the changes in vulnerability under hazard-generated impacts, taking as a case study two co-occurrent, independent hazards (i.e., floods and the COVID-19 pandemic) that severely affected a European country. At the outset, it is necessary to clarify the role of impacts resulting from multiple hazards in shaping vulnerability, with illustrative recent examples from the literature. These instances bring to light a notable research gap that requires investigation, as detailed in the following.*

Methodology

R1: *The number of different steps in the methodology make it very hard to follow. While interesting, it is a somewhat eclectic approach in certain areas. I do not agree with the comment "Elevating the Impact Chain from its above mentioned original purposes to a diagnosis and prediction tool represents a pioneering research endeavor, standing out as an element of methodological novelty". Rather, i feel that the entire paper should step away from the statement that you are predicting vulnerability dynamics, as it does not account for the myriad other factors that influence vulnerability (e.g. governance, development, systemic risks) etc etc.*

Response: We are thankful to the reviewer and agree that the methodology included too many steps and that the previous aim of the paper was extensive. By contracting the aim and simplifying the steps associated with the new objective, we removed 64% of the steps in the initial Methodology, and shortened this section by 27.78%. This is best illustrated in the new Figure 3. Methodological workflow.

We appreciate this suggestion of the reviewer, and we have also clarified the objective of the paper at lines 237-244 at the beginning of Methodology (and also in the Abstract): *The proposed methodological framework aims to identify and analyse the augmentation in vulnerability within a multi-hazard context. This framework dwells on Impact Chains as instruments for documentation, visualisation, organisation, and scientific inquiry, ultimately broadening their application to fit the latter objective of studying the dynamics of vulnerability – particularly the augmentation of vulnerability, and turning them into diagnosis and prediction tools. With this addition, the documentary focus of the chain progresses to a more analytical stance, specifically*

geared towards identifying and tracking the transformation of specific vulnerabilities into drivers of vulnerability, thus becoming a tool for multi-hazard management in predicting potential crises due to deficiencies in management approaches.

For an early clarification, we also ended the Introduction with a supplementary clarification (lines 109-119): *This research work makes a significant contribution to the field of DRR by broadening the original purpose of the Impact Chain, transforming it into a first-hand, semi-qualitative tool for analysing vulnerability. Through this expansion, the Impact Chain is elevated from a documentation tool to a diagnosis and prediction instrument. The focus is on advancing its application to delve into the intricate multi-hazard impacts, along with their ramifications on vulnerability conditions. The conceptual framework dwells on the argument of Otto and Raju (2023), who highlight that climate change should not be entirely blamed for climate-related disasters and that vulnerability conditions must be factored in when analysing impactful events. Placing greater emphasis on the vulnerability component brings up the necessity of understanding its dynamics across time and space (de Ruiter and van Loon 2022), and even more in multi-hazard situations. This can be achieved by expanding the scope of Impact Chains to give visibility to such shifts in vulnerability, to diagnose past or present multi-hazard risk management, and to predict potential crises, shortcomings of management approaches, and the transformation of certain vulnerabilities into drivers of vulnerability.*

The vulnerabilities included in the Impact Chain and in the manuscript include governance and development aspects. Some examples: improper governance structure for effective flood management, flood management not adapted to the COVID-19 context, ineffective institutional communication, development of inhabited areas in flood prone areas, development of infrastructure in flood prone areas, poverty, depleted capacity due to seasonal patterns of hazards, low quality construction materials, ineffective sewage system.
In order to eliminate any confusion, these vulnerabilities were highlighted at lines 537-542 in subsection 4.1 of the Results.

R1: *The ranking of vulnerabilities based on their augmentation is a step that you could consider removing from the publication, given its length and that it is trying to cover a lot for one paper.*

Response: The ranking of vulnerabilities based on their augmentation is part of the focus of the paper: to analyse the augmentation of vulnerability in a multi-hazard context. As we removed the aim and former Result subsection 4.1 (that dealt with the analysis of multi-hazard impacts within the Impact Chain), the length of the paper was drastically reduced.

Results

R1: *4.1 reads like a literature review. I do not see how it links to the methodology presented in the previous section. Are the impacts and events you are describing findings from the synthesis of literature and enhancing the impact chain? If so, state this. The main focus of the paper is how multi-hazard interaction and responses have*

augmented vulnerability. I suggest to focus of this and reduce the other findings to keep the narrative more easy to follow.

Response: Indeed, we revised and removed this section and focused the aim of the paper on the augmentation of vulnerability, as recommended by the reviewer. By doing so, the Results section was shortened and adapted to the changes implemented to Methodology.

Discussion

R1: *The discussion would benefit much more from reflecting on the methodology and its limitations. currently the limitations are mostly focused on data limitations, and not the limitations of the approach that you took, of which there are some significant ones. A discussion that looks at the novelty of the methods, and how they can be improved would significantly strengthen the paper.*

Response: We thank the reviewer for pointing out these shortcomings in the original version of the manuscript. We addressed the concerns by improving subsection 5.3. Limitations and constraints, adding the intrinsic limitations of the Impact Chain-based methodology from the perspective of the statistical approach (lines 133-136): *A notable methodological limitation refers to the lack of testing against other case studies and external validation; which we plan to address in the future by applying the methodological framework to other Impact Chains focusing on different multi-hazard case studies. Finally, the paper provides a limited view on the dynamic trajectory of vulnerability, relying only on two temporal pictures captured by the initial Impact Chain and the enhanced version of it.*

We will diligently take into account the recommendation of the reviewer, giving it careful consideration, and we will engage in thorough reflection on how we can improve the methodology in future papers. At this time, our interest is to centre the Discussion on the conceptual paths of increasing vulnerability, drawing exclusively from the events outlined in the enhanced Impact Chain. To further statistically test these conceptual paths is a future objective we intend to pursue in forthcoming research works.

The Discussion was modified to include a special subsection (5.2. Contribution and novelty) that describes the novelty of the methods and the contribution of the paper, as well as further steps we plan to implement to improve the proposed methodological framework. Changes were made between lines 97 and 117 to enhance readability.

Conclusions

R1: *Could be much sharper. The seven key take aways should be reduced to 2/3, that speak to the method you developed and the context specific findings form your case study.*

Response: To sharpen the outcome, we reduced the list of key takeaways from 7 to 5 specific findings worth keeping in mind by the reader, which were expressed in bullet form.

R1: *The statement that "Vulnerability is expected to increase due to inaction" is simply not true and is simplification of realty. interaction does not equal intensitication.*

Response: We generally agree with the reviewer, but we draw attention to a particularity of the Romanian society, expressed by facts summarised in the presented case study, in the Discussion section (lines 49-95). The absence of action has the potential to augment vulnerability because 1) the number of adaptation options is very low compared to the large number of vulnerabilities (13 to 26), meaning that many vulnerabilities are left unaddressed, 2) the adaptation options do not target multi-hazard, augmented vulnerabilities, but rather the impacts of the hazards (in the endeavour of addressing the symptoms of the crisis, and not its root causes), 3) the sequence of flood events and pandemic waves provides only a narrow timeframe to replenish capacity, which ends up depleted when facing the next flood/pandemic wave or even between flood events.

Minor comments

Abstract

R1: *Review the use of non-scientific language, which will make it more direct and easy to pull out the main messaging*

Response: The Abstract was rewritten removing the language indicated by the reviewer (page 1, lines 9-23.

Setting the scene

R1: *While the content is all relevant, i feel it can be shortened to get the message across more quickly.*

Response: We reduced the length of this section by 29.66%, from 1615 words to 1136 words.

Respectfully yours,
The Authors