

Author's response

MAJOR COMMENTS

- I feel the manuscript would work better if it was agnostic to the specific research project i.e. omit all mention of FloReST except for the acknowledgements, and couch the content instead on risk management of heavy rainfall events. At the moment it reads like an introduction to FloReST (e.g. Lines 212–4; 485–6)

Authors response: *We have completely removed any mention of the project name FloReST from the paper and instead refer to it in the acknowledgements.*

- The literature cited and Section 1 has a heavy German bias. I would suggest either noting down the regional focus in the title, or amending the Introduction to make it more general/global e.g. on Line 26, there is a big jump in the narrative from a general statement on climate change exacerbating pluvial flood events (on which note, the second sentence would benefit from additional citations and/or quantification) to the Ahr Valley floods, which will not immediately be familiar to the broad NHESS readership. I also suggest citing Rhein and Kreibich (2025) at this point - <https://nhess.copernicus.org/articles/25/581/2025/>

Authors response: *We have anchored the regional German focus in the title and noted this accordingly in the introduction. We have also expanded the literature. We have also added an introduction to the Ahr flood of 2021 and quoted Rhein and Kreibich (2025).*

- Several sections in the manuscript need more (or better) citations to back up statements made. For instance:
 1. Lines 27–28: “... continuous research is being conducted ...”
 2. Paragraph starting on Line 34 (“Risk management includes ...”) – particularly statements asserting that “valuable knowledge often resides with residents ...” about local/indigenous knowledge
 3. Line 63: “fluvial events, which are usually easy to predict ...” – really? Relative to pluvial or groundwater flooding?
 4. Line 80: “Risk management therefore has both an educational task ...”
 5. Line 82: Assertions about the poor predictability of pluvial events
 6. Line 92: “Currently there is often a gap ...”
 7. Line 129: “The most common method of CS is the questionnaire” – not sure that this is actually true.
 8. Section 2.3 – missing some important watery citizen science programs and initiatives, e.g. CrowdWater – see their website <https://crowdwater.ch/en/start/> - they have also published plenty of articles.
 9. Line 143 – on specific tailoring of apps to local communities. There is an entire literature on this, and knowledge co-production using apps, the Internet of Things etc (see Turner 2021 for one example - <https://www.tandfonline.com/doi/full/10.1080/02615479.2020.1762858>)

Authors response: *We have supplemented insufficient references and clarified general statements, as well as corrected critically noted statements. Furthermore, we*

have referred to other watery citizen science programmes and distinguished our project from the Crowd Water project.

- I suggest that Sections 1 and 2 be merged, as the narrative (as it stands) jumps around significantly, with citizen science being introduced briefly in the Introduction, before a more detailed consideration in Section 2.

Authors response: *We have retained the structure of introduction and literature review in accordance with the specifications. The introduction should provide a general introduction to the topic and the project. The literature review has been supplemented and better structured.*

- Citizen science needs a far more careful treatment. For instance, Bonn et al. (2002) is not an appropriate reference to back up the introductory statement of Section 2.2; you might want to have a look at Cohn (2008) or Irwin (1995) instead (full details below). Also – I am really not a fan of reviewers who ask authors to include a load of self-citations, but I would suggest at least glancing through Paul et al. (2018), which gives a flavour of many challenges and tradeoffs when utilising a citizen science framework in geohazard risk reduction / resilience building. There are also several papers that consider the utility of apps that might be consulted – look at the references within Paul et al. (2021) for starters.

Authors response: *We have supplemented the basic literature and better defined the term citizen science. We have also examined the benefits of apps in greater detail.*

- Two additions would greatly strengthen the citizen science discussion: (a) some mention of the need for apps to be “useful, useable, and used”, and steps that were / could be taken to ensure this; (b) more detail on the mechanics of citizen science projects, even down to potentially replacing “citizen” with “community” (see Ballard et al. 2024 - <https://www.tandfonline.com/doi/full/10.1080/13504622.2024.2348702>) – but also how participant motivation was dealt with, what incentives might have been needed, and steps that were taken to enhance project sustainability/legacy

Authors response:

(a) We did not explicitly address the narrative ‘useful, usable and used’. These points are addressed in sections 3.1.1 Design and functionality (usable), 5.1 Advantages of the Citizen and Community Science approach in emergency flood path management (useful) and 5.2.2 Thematic and data quality limitations (used), respectively.

(b) We introduced the terms citizen science and community science and distinguished between them. In this context, we defined our app as a hybrid form of citizen and community science.

- Line 103 – needs some acknowledgement that citizen science data are often criticised by the scientific community for its lack of accuracy and simplicity. This is another part of the manuscript that would benefit from blending with the corresponding part of Section 1. On a related note: on Line 102 (“The CS approach is a win-win situation ...”) – no! There is no recognition of the various negative externalities that can result from CS projects, such as lost community trust if results are not immediately forthcoming, or inaccurate / imprecise data, or zero data production altogether.

Authors response: *We have removed the positive wording ‘win-win situation’. The difficulties of the methodology in relation to citizens' expectations are also addressed in Section 5.2.2 Thematic and data quality limitations.*

- Line 108 – this is in Germany? Are there any comparable global statistics?

Authors response: *We have added a note stating that this is a German source. As we have placed the paper in a German context, we have refrained from using a global statistic here.*

- Can you strengthen the end of Section 2.2? Rather than including a saying or anecdote, why not instead discuss the importance of the polycentric governance of risk, starting from Elinor Ostrom’s suggestions (summarised here - <https://onlinelibrary.wiley.com/doi/full/10.1111/psj.12518>)

Authors response: *We have supplemented the end of Section 2.2 with a section on polycentric governance and placed it in the context of the app.*

- The overall concept is sound but it must be made clearer that the proposal is purely a proof-of-concept. The final paragraph of Section 2 (“... opens the possibility for various municipalities to use the project ...”) is very (over?)-optimistic and elides the significant technical, political, and regulatory challenges that might stand in the way of this level of operationalisation.

Authors response: *We explicitly framed the paper as a proof of concept and, for example, in Section “5.3 Scalability, future development and integration potential in other regions”, we clarified the stage the app is at and what steps would be necessary to make it usable in an international context.*

- 3–5 are just screenshots of the app? Might it not be preferable to include an additional schematic diagram of its intended operation and use?

Authors response: *For illustrative purposes, we have left the app images in the paper. These have been supplemented with two functional and use-case diagrams of the app:*

1. **Current application area:** *identification of trouble spots (e.g. recurrent water accumulation or vulnerable infrastructure) as a preventive measure for long-term adaptation (integrated in Section 4.1.1).*
2. **Potential extended function:** *real-time risk communication and decision support during heavy rainfall events (integrated in Section 5.3).*

- 100 I’ve explained more in the technical comments below about disjointed writing with very short paragraphs that could be merged. However, in some cases, the 1-sentence paragraphs should not be merged, but rather developed. For example, 100 is missing topic and closing sentences and there should be more examples added of how CS has been used in monitoring, especially for natural hazards since that is the focus of the research. Overall, your literature review is missing key references.

Authors response: *We have combined or supplemented short paragraphs. Insufficient references have been added and the bibliography expanded.*

- 121 “In CS projects, data should be collected by participants and sent for example to authorities or researchers.” – not necessarily, there are different levels of citizen science and participation.

Authors response: *We corrected the sentence to “Citizen science projects are typically characterised by being initiated predominantly by researchers (scientist-led), who also take primary responsibility for data analysis, while citizens are, in most cases, involved mainly in the collection of data (Ballard et al., 2024; Lin Hunter et al., 2023)”*

- 123 Is mD a common abbreviation for mobile devices? Is it necessary to abbreviate “mobile devices”?

Authors response: *We have changed the abbreviation mD to the full form ‘mobile devices’.*

- 138 Is this redundant information? The authors already mentioned questionnaires in an earlier paragraph.

Authors response: *We have left the sentence as it is. What is meant is that these data sources can also be integrated as part of the questionnaire.*

- 139 The authors could refer to the specific term “gamification” here i.e. the application of game design elements.

Authors response: *We have added a passage on gamification and its classification in the app context in section 2.3.*

- 144 The authors could also cite data quality issues here.

Authors response: *We have fundamentally revised this section.*

- 169 “When developing mobile apps, a distinction is made between web, native and hybrid apps.” As someone without a computer science background, these terms are quite foreign – a lot of jargon in this whole section.

Authors response: *We have thoroughly revised this section, using simpler language and reducing the number of technical terms.*

- 237 The methods section is missing the evaluation and use of the app by citizen scientists or authorities. For example, how did the authors administer the app and the evaluation survey?

Authors response: *We have added a section entitled ‘3.3 App prototype test procedure’ on the methods of evaluation and the app testing process carried out by participants.*

- 265 Good attention to privacy of personal data (but does the paper refer back to all tenets the authors presented at first in methods?)

Authors response: *The data protection measures actually implemented in the app are discussed in Section 4.3 “Data protection and security”.*

- 273 Is there an option for “other” if the given types do not apply?

Authors response: *Now there is no option for “other”, but you can describe the problematic area via text field, if necessary.*

- 291 disy Cadenza introduced is explained in section 4.2 but mentioned much earlier (for example in line 235)

Authors response: *We have moved the introductory explanation of disy Cadenza to the front in Section 3.2 ‘Geo Data Warehouse and data analytics platform’.*

- 325 Can citizens also access this data? What happens after they submit? How do the benefits come back to them?

Authors response: *Currently, citizens only receive feedback in the form of confirmation when they submit their report. We have elaborated on this in Section 4.1.1, ‘Process of data submission by citizens,’ and discussed it further in Sections 5.1, 5.2.1 and 5.2.2.*

- 339 There needs to be a methodology section that links to these results.

Authors response: *We have amended Section 3.2 “Geo Data Warehouse and data analytics platform” accordingly.*

- 348 Data? Evidence? Results of survey? This last section is like a methods section not a results section.

Authors response: *We have supplemented Section 4.4 ‘Performance analysis’ to match Section 3.3 ‘App prototype test procedure’ and included a participant's response as an example.*

- 353 Discussion starts with methods and results that weren’t presented before?

Authors response: *We have provided all the information relating to the evaluation. The survey mentioned at the beginning of the discussion chapter preceded the work and is not part of the app evaluation discussed here.*

- 371 Did the methods/results show this?

Authors response: *Yes. Participants' knowledge increased with use of the app.*

- 379 Where is the evidence from the data that links to this?

Authors response: *Without the data generated by the app, many municipalities would be unable to identify problem areas.*

- 404 Many instances throughout the Discussion section where statements are made but not backed up by the data or the literature, for example in this paragraph.

Authors response: *Part of the test procedures was carried out at a university. In addition, information about the app was shared during school visits on the topic of heavy rain and flooding.*

- 412 The authors mention a few times that the app was used by younger age individuals but did not explain how this was implemented – i.e. was a school partner involved?

Authors response: *Part of the test procedures was carried out at a university. In addition, information about the app was shared during school visits on the topic of heavy rain and flooding.*

- 420 Where are these results in the results section?

Authors response: *No matching text passage could be found. See notes below.*

- 459 Could it more likely be a data quality issue than deliberate? This is a common problem in CS.

Authors response: *Errors in data entry can certainly always occur. In the local context depicted here, we have experienced some highly emotionally charged situations in which participants simply wanted to express their anger.*

- 474 It is great that the app was developed to be open source, but are there any concrete plans for sustainability of the app/program?

Authors response: *The project has now come to an end. However, further projects are planned that will address the issue of flooding in the Ahr Valley, and a network called 'Wissenschaft für den Wiederaufbau (WfdW)' (Science for Reconstruction) has been established to disseminate and collate the results of previous projects.*

- 501 Was this mentioned in limitations or results?

Authors response: *No matching text passage could be found. See notes below.*

- Section 4.4: Performance Analysis – As previously mentioned this section is critical because it shows the data that are used to evaluate the app. However, the details of this evaluation have not been shared. You mention using a questionnaire before and after testing the app, but it is not clear what the testers were asked to do, and how the data were evaluated and whether or not the results are significant. I ask you to include the questionnaire (as supplementary material) and share relevant details such as the number of users testing the app, their background (if known and relevant) and the insights revealed by comparing their responses before and after testing the app.

Authors response: *We have added a section entitled '3.3 App prototype test procedure' on the methods of evaluation and the app testing process carried out by participants and added relevant information about the results. We also included a participant's response as an example. The questionnaire was added as supplementary material.*

Note: When processing Christine Liang's comments, we had some difficulty assigning the comments to the correct passages in the text, as some lines may have been misplaced. For this reason, we were unable to respond to two comments correctly. We have marked these comments accordingly.

MINOR COMMENTS / Technical Corrections

- Line 14 – remove “a” before “user guidance”

Authors response: *We have corrected this minor comment.*

- Line 36 – remove “a” before “runoff”

Authors response: *We have corrected this minor comment.*

- Line 78: The level of education ... is (not are)

Authors response: *We have corrected this minor comment.*

- Line 85: be developed (not are)

Authors response: *We have corrected this minor comment.*

- Line 86: be improved (not is)

Authors response: *We have corrected this minor comment.*

- Line 148: “a new software will be programmed as CS project” – this is unclear

Authors response: *We have corrected this minor comment and clarified the sentence.*

- 1: Map display (not displan)

Authors response: *We have corrected this minor comment.*

- Line 239: “sustainable risk management in heavy rain prevention” – this is a little unclear; rain can’t be prevented

Authors response: *We have corrected this minor comment and clarified the sentence.*

- 25 The paragraphs throughout the introduction and literature review are quite short – sometimes one sentence has its own paragraph. This makes the writing look disjointed and interrupts flow.

Authors response: *We have combined or supplemented short paragraphs.*

- 25-28, 44, 47, 62 The introduction and literature review sections seem to be missing references.

Authors response: *Insufficient references have been added and the bibliography expanded.*

- 67, 80 Example of 1-sentence paragraphs that should be merged with the above paragraph as a closing sentence. Especially with 80, the authors write “therefore” so it should be linked with the above paragraph.

Authors response: *We have combined 1-sentence paragraphs and supplemented short paragraphs.*

- 124 Missing reference.

Authors response: *We have corrected this minor comment.*

- 148 The writing is awkward at times and sounds clunky and confusing. For example, check this sentence. Have someone check writing throughout.

Authors response: *We have revised the paper linguistically.*

- 150 The authors use inconsistent US or UK spelling, for example here sometimes words are spelled with s and sometimes z. Here “organise” is spelled the UK way with an “s”. The authors spell other words with “z” i.e. the US way. Be consistent.

Authors response: *We have revised the language of the paper and converted all US versions into British English.*

- 185 Figure 1 in the green box says “map displa” – is this a typo?

Authors response: *Yes, it was a typo. We have corrected this minor comment.*

- 221 Is there a reason for the switch to footnotes here versus in-text citations?

Authors response: *This is a reference to further documentation and not a bibliographical reference. For this reason, the reference has been included as a footnote.*

- 309 As in comment 150. “The color-coded dots each represent a single report, coloured according to the categorization of problem area.” – this sentence mixes both US and UK spellings of “color/colour”. Pick one style of English and be consistent.

Authors response: *We have revised the language of the paper and converted all US versions into British English.*

- 375 Delete paragraph break after open bracket.

Authors response: *We have corrected this minor comment.*

- Figures 3 and 5 – Please add letters a-d to each panel in the figure so the caption is more clear.

Authors response: *We have supplemented the illustrations accordingly and clarified the relevant information in the text.*